

NATIONAL SCIENCE FOUNDATION AUTHORIZATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

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ON

NATIONAL SCIENCE FOUNDATION AUTHORIZATION

FEBRUARY 22 AND 23, 1984

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(II)

CONTENTS

Opening statement by Senator Gorton	Page 1
---	-----------

CHRONOLOGICAL LIST OF WITNESSES

FEBRUARY 22, 1984

Knapp, Dr. Edward A., Director, National Science Foundation; and Dr. Walter A. Massey, member, National Science Board, director, Argonne National Laboratory	2
Prepared statement of Dr. Knapp	4
Prepared statement of Dr. Massey	11
White, Dr. Robert, president, National Academy of Engineering	27
Prepared statement	30

FEBRUARY 23, 1984

Opening statement by Senator Gorton	37
Opening statement by Senator Heflin	38
Keyworth, Dr. George A., II, Science Adviser to the President	39
Prepared statement	49
Knapp, Dr. Edward A., Director, National Science Foundation; Dr. Neal Lane, chairman, Physics Department, Rice University; and Dr. Richard A. Zdanis, chairman, vice provost, Johns Hopkins University	57
Prepared statement of Dr. Knapp	62
Prepared statement of Dr. Lane	69
Prepared statement of Dr. Zdanis	74
Attachments	78

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

American Psychological Association, statement	97
American Society of Civil Engineers, statement	115
Cooney, Joan Ganz, president, Children's Television Workshop, letter of February 17, 1984	116
Harrison, Anna J., president, American Association for the Advancement of Science, statement	98
Kersten, Dr. Robert D., P.E., dean of the College of Engineering, University of Central Florida, statement	106
Miller, Dr. Roberta Balstad, executive director, Consortium of Social Science Associations, statement	110
National Institute for Entrepreneurial Technology, statement	114
Snoyer, Dr. Robert S., president, SNOCO, Inc., letter of March 9, 1984	117

NATIONAL SCIENCE FOUNDATION AUTHORIZATION

WEDNESDAY, FEBRUARY 22, 1984

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:37 a.m., in room SR-253, Russell Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding.

Staff members assigned to these hearings: Cheryl Coodley, professional staff member, and Steven Flajser, minority professional staff member.

OPENING STATEMENT BY SENATOR GORTON

Senator GORTON. The committee will come to order.

Welcome to this hearing on plans and programs of the National Science Foundation for fiscal year 1985. This will be the first of 2 days of hearings, the second of which will take place tomorrow.

The National Science Foundation is unique among Federal agencies. Its primary mission is to support fundamental research in virtually every field of science and engineering. The Foundation funds projects ranging from the development of mathematical models to explain how individual cells organize into living animals, to the identification of distant galaxies which offer clues as to the origin of our universe.

For the upcoming year, I am delighted to see that the proposed budget for the National Science Foundation provides real growth in almost all the major programs of the agency. This year, the proposed budget represents an increase of about 14 percent for the Foundation as a whole. Even greater increases are proposed for certain research and related activities, including mathematics and physical sciences, and engineering.

Initiatives in supercomputers and research instrumentation are also highlights of the proposed budget. I am also pleased to see that funding for social and behavioral science research has been increased. Since we cannot cover in detail every area of the Foundation, our hearings today and tomorrow will focus on several areas of tremendous and current interest: Engineering initiatives, including university-industry cooperative programs, research instrumentation, and supercomputers.

Today we will focus on engineering initiatives, including existing and new university-industry cooperative programs. At last year's NSF hearings, this subcommittee spent a day hearing from univer-

sity and industry leaders about the role of university-industry cooperative links. Such links are not new. Indeed, they antedate large-scale Federal support of research. University-industry cooperative research cannot substitute for Federal support of basic research, but cooperation can and does serve a vital role in its potential for technology transfer and in the benefits to faculty, students, and industry from the exchange of information.

We begin today with an overview from Dr. Edward Knapp, Director of the Foundation, joined by Dr. Walter Massey, a member of the National Science Board, director of Argonne National Laboratory, and vice president for research at the University of Chicago. Then we will focus on engineering initiatives with Dr. Knapp and Dr. Massey, and we will hear from Dr. Robert White, president of the National Academy of Engineers.

Dr. Knapp and Dr. Massey, welcome. We will proceed with Dr. Knapp first, or you may take it in whichever way you think appropriate.

STATEMENTS OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION; AND DR. WALTER E. MASSEY, MEMBER, NATIONAL SCIENCE BOARD, DIRECTOR, ARGONNE NATIONAL LABORATORY

Dr. KNAPP. Thank you, Mr. Chairman.

I am pleased to be here for the first 2 days of hearings on the administration's fiscal year 1985 budget request for the National Science Foundation. With me this morning is Dr. Walter E. Massey, a member of the National Science Board. He is director of the Argonne National Laboratory and also vice president for research programs at the University of Chicago.

When I have completed my brief overview of the Foundation's plans and programs for fiscal year 1985, Dr. Massey will describe the role of the National Science Board and the part it plays in establishing our priorities and programs.

We have brought a film which, with your permission, I would like to show the committee. I believe it sets the right tone for my review of the Foundation's research and educational activities and how they contribute to our country's future.

[Film shown.]

Dr. KNAPP. I think this gives us an excellent introduction to the wide variety of programs the Foundation supports and to the way in which education and research in science and engineering are so closely intertwined.

Mr. Chairman, our budget for 1985 is \$1.5 billion, an increase of 13.6 percent above fiscal year 1984. Our proposed programs build on and strengthen those of last year. We are also requesting support for some exciting new initiatives. This proposed budget reflects the administration's deep commitment to excellence in our country's pursuit of scientific and technological advances and to the training of our future scientists and engineers. It also reflects the very strong support which the Foundation's programs received from this committee and the Congress last year.

We used several important criteria to formulate our request for 1985. These included the scientific excellence and promise of each

activity; the need to sustain scientific momentum in certain key areas; maintenance of our broad base of support across a wide variety of science and engineering disciplines, including provisions for advanced equipment and facilities; an activity's potential contributions to important national goals; and the need to improve education and training for future scientists and engineers.

Let me mention some highlights of our 1985 program. To help astronomers understand the structure of the universe, we are requesting funds to begin construction of the very long baseline array, VLBA. This array will produce radio images capable of seeing features about the size of a dime in New York as seen from Los Angeles.

Construction of the VLBA will require approximately 4 years and will consist of antennas located across the United States from Hawaii to Puerto Rico. This facility is the highest priority ground-based instrument recommended by both the Academy of Science's study of astronomy and the astronomy community with our advisory committees.

We are proposing a new program to establish cross-disciplinary research centers in engineering. This initiative grew out of a year-long review by the Foundation and the Office of Science and Technology Policy which studied ways to strengthen the research and educational capabilities of the Nation's engineering schools. Virtually everyone concerned with this issue agrees we must strengthen engineering schools if we are to maintain our productive capacity and economic competitiveness with other industrial nations.

We believe that these engineering centers will contribute greatly to this important national objective. Recent studies and workshops have documented the growing opportunities and unfilled needs in advanced scientific computing. In some research areas, advances are now completely dependent on access to the most powerful scientific computational resources.

Our request this year continues and expands the efforts we began in fiscal year 1984 to address the advanced computational needs of researchers in all disciplines. We will increase support for predominantly undergraduate institutions by 15 percent. This support will offer greater opportunities for faculty and students to gain hands-on experience with the latest scientific instrumentation and research techniques.

Last week, recipients of the first Presidential Young Investigator Awards were announced. With matching funds and participation from the industrial sector, these awards are intended to encourage promising young investigators to remain in academic careers. This will insure the excellence of graduate science and engineering education and research.

We will be supporting 200 additional young investigators for a total of 400 in 1985. Half of these will be in engineering.

In 1985, we will initiate new research on the understanding of life, emphasizing the chemistry of life processes. Multidisciplinary research requiring the cooperation of chemists and biologists will facilitate the development of such knowledge which is essential for biotechnology related to medicine and agriculture.

Mr. Chairman, the National Science Board has worked with me, the Foundation staff, and many of the Foundation's advisory

groups as well as the National Academy of Sciences and Engineering for almost a year to shape the priorities which you see expressed in our budget request.

At this time, I would like to ask Dr. Walter Massey to describe the important role the Board has played. In particular, his comments illustrate their part in the development of some of the exciting initiatives we are proposing. Dr. Massey.

[The statement follows:]

STATEMENT OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. Chairman and Members of the Committee, I am pleased to be with you for the first of two days of Hearings on the Administration's fiscal year 1985 budget request for the National Science Foundation.

With me this morning is Dr. Walter E. Massey, a member of the National Science Board and Director of the Argonne National Laboratory. When I have completed my brief overview of the Foundation and its planned program for fiscal year 1985. Dr. Massey will describe the role of the National Science Board and the part it plays in establishing our priorities and programs. I will then describe, in more detail, two topics that I know are of particular interest to you. Mr. Chairman: (1) The Foundation's stewardship of the U.S. Antarctic Program and our plans for it in fiscal year 1985; and (2) some of the many ways in which the Foundation's programs promote the critical linkages between our Nation's universities and colleges and industry. I will give particular attention to our plans in engineering.

We have brought a film which, with your permission, I would like to show the Committee. I believe it sets the right tone for my review of the Foundation's research and educational activities and how they contribute to our country's future.

I think this gives us an excellent introduction to the wide variety of programs the Foundation supports and to the way in which education and research in science and engineering are so closely intertwined.

THE FISCAL YEAR 1985 REQUEST: AN OVERVIEW

Mr. Chairman, our budget request for fiscal year 1985 is \$1.5 billion, an increase of 13.6 percent above fiscal year 1984. Our proposed programs build on and strengthen those of last year. We are also requesting support for some exciting new initiatives. This proposed budget reflects the Administration's deep commitment to excellence in our country's pursuit of scientific and technological advances and to the training of our future scientists and engineers. It also reflects their very strong support which the Foundation's programs received from this Committee and the Congress last year.

We used several important criteria to formulate our request for fiscal year 1985. These included: the scientific excellence and promise of each activity; the need to sustain scientific momentum in certain key areas; maintenance of our board base of support across a wide variety of science and engineering disciplines, including provisions for advanced equipment and facilities; an activity's potential contributions to important national goals; and the need to improve education and training for future scientists and engineers. We believe that the result is a strong, well balanced program of exciting basic research, with particular emphasis on areas that may contribute most to our continued economic well-being and technological capabilities.

Let me mention some highlights of our fiscal year 1985 program.

To help astronomers understand the structure of the universe, we are requesting funds to begin construction of the Very Long Baseline Array (VLBA). This array will produce radio images capable of "seeing" features down to 0.3 milli-arc seconds, or about the size of a dime in New York as seen from Los Angeles. Construction of the VLBA will require approximately four years and will consist of antennas located across the United States from Hawaii to Puerto Rico.

We are proposing a new program to establish cross-disciplinary research centers in engineering. This initiative grew out of a year-long review by the Foundation and the Office of Science and Technology Policy which studied ways to strengthen the research and educational capabilities of the Nation's engineering schools. Dr. Robert White, President of the National Academy of Engineering, is scheduled to testify before you later. I am certain that his remarks will make clear the significance of the Academy's role in this review. Virtually everyone concerned with this issue agrees that we must strengthen engineering schools if we are to maintain our productive capacity and economic competitiveness with other industrial nations. We be-

lieve that these engineering centers will contribute greatly to this important national objective.

Recent studies and workshops have documented the growing opportunities and unfilled needs in advanced scientific computing. In some research areas advances are now completely dependent on access to the most powerful, scientific computational resources. Our request this year continues and expands the efforts we began in fiscal year 1984 to address the advanced computational needs of researchers in all disciplines. With this funding we will support networking capability, local user support, and facilities. Moreover, the National Center for Atmospheric Research will acquire an Advanced Vector Computer, a research tool that will significantly advance our understanding of atmospheric and oceanographic phenomena.

We will increase support for research at predominantly undergraduate institutions by over 15 percent. These institutions provide undergraduate training for many of our Nation's future scientists and engineers. This support will offer greater opportunities for faculty and students to gain hands-on experience with the latest scientific instrumentation and research techniques.

Last week, recipients of the first Presidential Young Investigator awards were announced. With matching funds and participation from the industrial sector, these awards are intended to encourage promising young investigators to remain in academic careers. This will ensure the excellence of graduate science and engineering education and research. We will be supporting 200 additional young investigators for a total of 400 in fiscal year 1985. Half of these will be in engineering.

Increasingly sensitive analytical techniques allow us to probe the details of chemical change in systems of extreme molecular complexity. Recent advances in molecular biology and biochemistry, such as the chemical synthesis of artificial genes, make it abundantly evident that we are at the threshold of major advances in understanding life processes. The ultimate understanding of life processes depends on their examination at the molecular level by the techniques of chemistry.

In fiscal year 1985, we will initiate new research on the understanding of life emphasizing the chemistry of life processes. Multidisciplinary research, requiring the cooperation of chemists and biologists, will facilitate the development of such knowledge which is essential for biotechnology related to medicine and agriculture.

Mr. Chairman, the National Science Board has worked with me, the Foundation staff, and many of the Foundation's advisory groups as well as the National Academies of Sciences and Engineering for almost a year to shape the priorities which you see expressed in our Budget Request. At this time, I would like to ask Dr. Massey to describe the important role the board has played. In particular, his comments illustrate their part in the development of some of the exciting initiatives we are proposing.

U.S. ANTARCTIC PROGRAM

Mr. Chairman, I would now like to discuss one of the important activities in our Budget Request—the U.S. Antarctic Program (USAP). Conducted by NSF as a national program, USAP and the scientific research it supports are the principal expression of our Nation's presence in Antarctica and a requisite for U.S. support of the Antarctic Treaty. In fiscal year 1985 we are requesting \$115.1 million for this program, an increase of \$12.6 million over fiscal year 1984.

The Foundation has supported research on this continent since the International Geophysical Year in the mid-1950's. In fiscal year 1972, a Presidential directive consolidated funding and management responsibilities for the various Federal activities carried out in Antarctica under the National Science Foundation. This role was reaffirmed in 1976 and again in February 1982 in a Memorandum signed by President Reagan. This Memorandum recognized that these Antarctic responsibilities are over and above the normal activities of the NSF and directed that they should be supported accordingly.

In May 1983, the Office of Management and Budget, at the request of the Senate Committee on Appropriations, reported on an in-depth study of the U.S. Antarctic program. The study concluded that the Foundation is a competent manager of this national program and that no other single agency could logically replace NSF in this role. The Congress established a separate appropriation for USAP for fiscal year 1984.

The research supported in Antarctica increases knowledge of that continent—which constitutes fully 10 percent of the earth's surface—and the surrounding stormy seas. Scientists conduct research at four locations: two coastal stations, one at the base of the Antarctic peninsula, and one at the South Pole which you saw earlier in the film. Scientists also conduct research aboard ships and through

remote sensing techniques using satellites, aircraft, rockets, balloons, and unmanned stations.

The basic research in geology, geophysics, and oceanography performed in Antarctica improves our understanding of the resource potential of the continent and its significance in world weather patterns. The United States also conducts mapping and charting, operates weather observatories, and does ice forecasting there. The Antarctic Policy Group, chaired by the Department of State, is responsible for providing policy guidance regarding program content. The Polar Research Board of the National Academy of Sciences provides continuing advice on scientific opportunities and priorities.

The Naval Support Force provides primary logistics support for the program on a reimbursable basis. This includes some operations and maintenance at McMurdo Station and the year-round operation of an air squadron which has seven NSF-owned ski-equipped LC-130 aircraft and six navy helicopters.

Since one LC-130 aircraft has reached the end of its useful life and a second will do so shortly, we instituted a service life extension program in fiscal year 1984. Five million dollars was requested and appropriated as the first installment.

Unfortunately, this program has been delayed because of major contract negotiation problems between the Department of Defense and private contractors. These delays could make the planned service life extension economically infeasible. Currently, the Naval Air System Command is preparing alternatives for the Foundation's consideration. If the two older aircraft cannot be upgraded satisfactorily we may need to consider buying one or two new aircraft.

A private contractor operates South Pole, Siple and Palmer Stations and performs all construction on the continent. The contractor also carries out a major part of the operations and maintenance at McMurdo Station.

The Department of Transportation, through the U.S. Coast Guard, provides icebreaker support to the Program. Icebreakers make a channel through the ice of McMurdo Station and also provide for the annual resupply of Palmer Station. At present the Foundation reimburses the U.S. Coast Guard on an annual basis for a share of the total fixed costs of the U.S. Icebreaker fleet and for an appropriate share of the operational cost. Both costs depend upon the number of icebreaker days devoted to NSF-supported programs. In fiscal year 1984 we estimate the cost at \$15 million.

Finally, we continue to restore or replace obsolete facilities, particularly at McMurdo Station. Major construction projects started in prior years will continue and the salt water distillation plant should be complete and operating in fiscal year 1985. Design work for the heavy maintenance facility was completed in fiscal year 1984 and actual construction will begin in fiscal year 1985.

Mr. Chairman, I would like to focus my remaining remarks on a topic of great interest to this Committee and to the Foundation: the ties between our universities and colleges and our nation's industries. Dr. Massey has already described the Board's continuing interest in industry/university relations and in engineering and the Foundation's role in enhancing them. I would like to build on his remarks and tell you about some pertinent plans and activities in our fiscal year 1985 request.

Mr. Chairman, our Nation's universities are unique in that they produce both scientific and engineering knowledge and trained scientists and engineers.

I would like to convey some sense of the importance of this trained manpower to the economy by briefly presenting figures on the employment of doctoral scientists in business and industry. In 1981, this sector employed 56 percent of the Nation's doctoral engineers, 53 percent of the doctoral chemists and 58 percent of the doctoral computer specialists. Between 1973 and 1981, the proportion of doctorate scientists and engineers employed in industry increased significantly. The number of doctorate mathematicians and engineers rose by almost 75 percent, computer specialists by over 400 percent. These individuals, trained in our universities and colleges at the leading edge of research and engineering technologies, are the single most significant linchpin in industry/industry relations. They are central to this Nation's technological and scientific leadership and industrial competitiveness.

Foundation programs in fiscal year 1985 will contribute directly to enhancing the quality of doctoral scientists and engineers produced by our universities and colleges in a variety of ways.

We have increased support for graduate students on research awards by 15.5 percent to a total of \$103.4 million in fiscal year 1985. We estimate that over 11,000 students will work as graduate research assistants on research projects funded by the Foundation. This first-hand experience, performing significant research tasks, ensures excellent scientists and engineers in the future.

Each of the centers in our new initiative for cross-disciplinary engineering research will focus on a particular subject of national importance like computer-integrated manufacturing, biotechnology processing, materials processing, or construction. Each will generally include participation of companies or industrial associations in order to focus the research activities on technologically significant areas and provide hands-on experience in modern engineering practice. The rich, cross-disciplinary research and learning environment of these centers will better prepare students for entering the multi-disciplinary world of industrial practice. It also will give them first hand exposure to the most advanced engineering research and technologies.

On the research front, many of the Foundation's activities will continue to contribute directly to the vital link between our academic institutions and industry by increasing research support for basic work in critically important scientific and technical areas. I would like to describe some of these for you.

In fiscal year 1981, we started a coordinated program for establishing a modern, experimental university computer research capability. The purpose of this program was to help universities to undertake improved, long-range experimental work in this rapidly changing field. At the same time, this program created the research environment necessary to attract and retain the faculty and students so urgently needed in this industrially significant area. In fiscal year 1985 we will increase support for these coordinated research facilities by over 25 percent. This will permit an additional 4-5 new facilities, bringing the total to around 24.

In the everyday world, "materials" means concrete, lumber and steel. In today's research world, the focus is on new materials not occurring in nature that can be fundamentally important to American industry.

Research on these new materials, often requires a team of scientists, each with different skills and training in physics, chemistry and engineering. Since 1972 NSF has sponsored such interdisciplinary research through its Materials Research Laboratories at 14 universities. A number of recently successful research projects illustrate the character of their work as well as the nature of their interactions with industry.

Materials engineers and physicists at the Stanford University MRL, together with crystal growing experts at Bell Laboratories, developed a new way of manufacturing single crystal optical fibers. The single crystal material results in fiber optics which greatly improves the effectiveness of communication systems. Another group of metallurgists and physicists at the Harvard University MRL is studying the properties of new types of metallic alloys which have a glassy structure. The General Electric Company, which provides some of their samples, uses these materials for designing more efficient transformers. Metallic glasses have potential technological importance because they demonstrate superior strength and anticorrosive properties.

In fiscal year 1985, we will increase support for such work through our MRL's by almost 14 percent to a total of \$30.0 million.

The Industry/University Cooperative Research Projects program is yet another activity which explicitly fosters joint research by academic and industrial scientists.

An investigator at the University of Arizona, for example, is working with Bell Laboratory scientists to create the optical equivalent of a transistor for logic circuits in fiber optic communication systems. This research is aimed at uncovering the knowledge needed to develop practical devices that would permit future development of extremely high speed optical and signal processing systems. One industrial scientist is providing the theoretical work, the other is providing special material samples using the Bell Labs advanced molecular beam epitaxy equipment. The university scientist is performing the experimental work.

In fiscal year 1985, support for the Industry/University Cooperative program is \$7.0 million with an identical amount to be provided by other NSF research activities for a total of \$14.0 million.

The Foundation's Research Instrumentation Facilities program was established in 1978 to give academic, governmental and industrial scientists access to expensive, sophisticated, specialized instrumentation such as lasers, nuclear magnetic resonance spectrometers, mass spectrometers and electron microscopes. In fiscal year 1985, there will be 14 of these regional facilities located at universities across the United States. They will be supported at a level of \$3.8 million.

Industrial users many times working side by side with university scientists and engineers, have ranged from small businesses to the Fortune 500. The Control Data Corporation, for example, used mass spectrometry techniques at the University of Nebraska facility to identify trace amounts of surface active agents that were contaminating computer discs, causing them to malfunction. Aerodyne Research, a small company in Bedford, Massachusetts, used the MIT facility to characterize the

optical properties of selenium compounds for possible use in advanced optical devices.

Since 1973, the Foundation has provided support for the planning and operating phases of a number of industry-university cooperative research centers. We designed this activity to provide the seed money for establishing self-sustaining centers at universities which are supported by industry and emphasize research in areas that are responsive to industrial technical needs and university interests. NSF support usually lasts from 3 to 5 years at a decreasing level. Industrial and, since 1982, state funds make up the difference.

At present, 12 Centers are operating with 120 faculty members, 18 postdoctorals, 195 graduate students and 29 undergraduates. There are 173 industry memberships supported by 118 companies. Since 1972, the Foundation has provided almost \$11.0 million and matching funds from industry have equaled an estimated \$16.0 million. In fiscal year 1984, state support is expected to total \$10.0 million.

In the fiscal year 1985 Budget Request, \$3.0 million will be used for these highly successful examples of NSF sponsored university/industry research and training. These funds will support faculty-student research and projects like one conducted at the Ohio State University Center for Welding research.

Industry has needed high quality, reliable welds, at reasonable costs, for a long-time. University researchers at Ohio State did the theoretical and experimental work necessary to create a laboratory prototype for an automated welding system capable of making complex, curvilinear, high strength welds on a production line. General Electric, the industrial partner, further developed and commercialized the process, patented it, and released it under the trade name of "Weld Vision."

CONCLUSION

Mr. Chairman, I believe that the National Science Foundation's programs have contributed and will continue to contribute to the long-term technological strength and economic competitiveness of the United States. We have a significant and long track record of encouraging, supporting and participating in the kind of university/industry research and educational linkages which are so vital to this long-term strength.

The Administration's fiscal year 1985 Budget Request for the Foundation builds upon this track record and proposes some exciting new initiatives—in astronomy, engineering, advanced computing, chemistry, materials, biological processes—which will substantially enhance these efforts. I am pleased to recommend it to you and your Committee this morning.

I would be pleased to answer any questions you now have.

Dr. MASSEY. Thank you.

Mr. Chairman, it is a pleasure to appear before you this morning to discuss recent activities of the National Science Board in areas of importance to the U.S. scientific capability and the economic viability that lie behind the fiscal year 1985 budget request that is before you.

The National Science Board is charged by the Congress with the health of America's science and engineering capabilities, both research and education. Working with the Director and his senior staff, we spend a large part of our time each year coming to grips with the issue of balancing priorities for the NSF's programs in ways that promise to strengthen both science and engineering and their contribution to the Nation.

With regard to the research programs of the Foundation, the Board is pleased to support this budget that offers a balanced strengthening of all fields of science and engineering while focusing especially on areas that are ripe for advance.

I have described in some detail in my written testimony the processes we use in decisionmaking on the Board. I would like now to review some of the outcomes of this process. I will focus especially on three areas, industry-university research cooperation, research

in and access to scientific computing, and the engineering mission of the National Science Foundation.

The committee has the documents to which I will refer, but we will be pleased to provide additional copies if they are needed.

The Board's annual report last year highlighted the growing importance to both universities and industrial firms of industry-university research cooperation. The studies that lay behind that report have just been published and made available to you. They describe a dynamic situation with a rapid growth of scientific and engineering cooperation driven by natural forces that will be good for both groups of institutions.

Private industry looks to our research universities for trained people and for the results of fundamental research in science and engineering, both of which are essential to firms' abilities to innovate and increase their productivity. Cooperation between universities and industry is growing rapidly, and we hope our leadership, our report, and the studies recently published will contribute to an understanding of both the risks involved in such cooperation and the great potential benefits that it offers to universities, to industry, and to the country as a whole.

The Foundation's early encouragement, beginning over a decade ago, has helped trigger industry-university research cooperation and continues to nurture it. For example, we have supported joint projects and centers for a number of years. In addition to these programs, this year's budget includes a major focus on making budget investments in several fields where university-industry relationships have the most immediate benefit to our economy, namely, engineering, materials science, and computing.

In scientific computing, the Board has encouraged the Foundation to respond both to the need to enhance access by research scientists to large-scale scientific computers and to support advanced research in new ideas for the design of high-speed computers.

Professor Peter Lax, a Board member, brought these issues before the Board and headed a group, sponsored by DOD and NSF, that prepared a report on large-scale computing in science and engineering. This report presented the need for making advanced computing resources available to the research communities. The Director then organized a series of internal studies which the Board reviewed and endorsed. They have led to an initiative in this budget and to upgrade the access by scientists and engineers to large-scale computing.

Let me review in somewhat greater detail what I believe to be one of our most important accomplishments during the past year, our policy guidance on the engineering mission of the NSF over the next decade. Mr. Chairman, with your permission, I would like to submit our policy statement for the record. The Board has brought several years' work to a successful conclusion this past June.

I believe the new directions will be strongly supported by the engineering community. The National Academy of Engineering, for example, has provided us with many detailed ideas on how our policies could be implemented, and I am sure Dr. White will have more to say about that later.

Engineering and manufacturing processes have been transformed by the introduction of computers, telecommunications, and infor-

mation management into every phase of the industrial environment for engineering and manufacturing. Engineering education and research capabilities in our universities must respond and adjust, a demanding task.

The Board concluded that to meet the challenge to the Nation's engineering strength and therefore to its economy and security, the National Science Foundation should expand and alter its traditional role in support of engineering sciences at academic institutions. The Foundation is already taking important steps to deal with the development of engineering faculty and to upgrade university research instrumentation.

In addition, the Board believes that, one, the Foundation should provide increased support for the engineering sciences to expand the frontiers of knowledge and practice and because of their importance to the U.S. economic health and security. This should include a number of areas where little support is now provided, such as software engineering, magnetic technology, bioengineering, and plasma engineering.

Second, the NSF should promote the appropriate use of computers to engineering education and research, address problems in availability and accessibility of software and hardware, and increase its participation in advancing computer engineering and other areas fundamental to computer design and implementation.

Third, the NSF should increase its support for research, education and training, and transfer of knowledge and technology between academe and industry in a variety of areas, including engineering processes, materials processing, and manufacturing systems engineering.

And fourth, the NSF should strengthen the base of academic engineering by encouraging faculty development and growth, providing suitable instrumentation and facilities and improving educational and training methods where needed. These changed directions in NSF's engineering research and education programs will develop over the next few years. If successful the Foundation can help our engineering schools produce graduates who are both more effective in research and better trained to enhance the Nation's productivity and competitiveness. We are excited at the prospect and urge you to help us pursue this opportunity.

Finally, I will touch on a proposed amendment to the NSF Act which has been submitted to you at the request of the Board. The amendment would treble the maximum dollar amount of awards for which the Board may delegate approval authority to the Director from \$2 million in total or \$500,000 in any one year to \$6 million in total or \$1.5 million in any one year.

We request this change to reflect inflation since 1968, the time at which the existing provision was enacted. The purpose of our request is to exercise more effective oversight over Foundation programs. By reducing the number of individual grants we are required to review based on a dollar limit, we will have more time to review overall programs and selected projects based on other equally important criteria.

We will, for example, want to look in more depth at programs that are new initiatives or those that have special policy significance. I urge that you approve this amendment.

Mr. Chairman, during the past year, the Board has dealt successfully with major issues that will have a significant impact on the Nation's scientific and technological future. We have developed an important level of consensus on these issues, clearing the way for effective action. The Director, with the support of the administration, has moved expeditiously and strongly to implement the strategic directions for the National Science Foundation. We urge you and the members of your committee to support these directions. Thank you for this opportunity to testify.

Senator GORTON. Dr. Knapp, before we go back to you, all of Dr. Massey's statement, including the parts skipped in his oral presentation, will be included in the record; and will also include the reports to which you referred.¹

[The statement follows:]

STATEMENT OF DR. WALTER E. MASSEY, MEMBER, NATIONAL SCIENCE BOARD

Mr. Chairman and members of the subcommittee, I am Walter E. Massey, member of the National Science Board, whose Planning and Policy Committee I chair. I am also Director of the Argonne National Laboratory.

It is my pleasure to appear before you this morning to discuss recent activities of the Board in areas of importance to U.S. scientific capabilities and national economic vitality that lie behind the Fiscal Year 1985 budget request before you.

ROLE OF THE NATIONAL SCIENCE BOARD

The National Science Board is charged by the Congress with a concern for the health of America's science and engineering capabilities—both research and education. Working with the Director and his senior staff, we spend a large part of our time each year coming to grips with the issue of balancing priorities for NSF's programs in ways that promise to strengthen both science and engineering and their contributions to the Nation. With regard to the research programs of the Foundation the Board is pleased to support this budget, that offers a balanced strengthening of all fields of science and engineering, while focusing especially on areas that are ripe for advance.

Let me briefly describe how we participate in development of the plans that become the basis for the budget. Each year, Board members have a series of formal and informal discussions with the Director and assistant Directors of NSF and representatives of the scientific community about priorities in areas of science and engineering. The Board's Planning and Policy Committee, which I chair, serves as an arena for deliberation and debate; a vehicle for formulating recommendations; a review mechanism for policy implications of issues addressed by the Board; and an organizing instrument for two major deliberative activities of the Board—the June meeting where we do in-depth work on two or three very significant topics and the winter planning and policy discussions that feed directly into developing the budget request for the following year.

Last week's Board meeting was the culmination of the winter long-range planning activity. It provided an opportunity for intensive interaction between Board members and senior NSF staff in discussing the opportunities and problems faced by the Foundation as a whole and by individual Directorates and programs. This planning activity began last fall with the issuance by the Director of his Planning Environment Statement, a document that integrated broad national concerns relevant to NSF, external influences on the Foundation, policy guidance from the Board and Director, and guidance for the winter's planning activities. In the context of that statement, each Directorate, working with the Director's staff and with Board members, then developed a draft long-range plan. These plans were integrated by the Director, working with the Board, into a long-range planning document for the Foundation, the draft of which we reviewed last week. When made final, this planning document will establish a set of priorities which the Director and the Board's Budget Committee can then utilize in formulating fiscal year 1986 budget recommendations to OMB in September.

¹ The reports referred to have been retained in the committee files.

Let me now review some of the outcomes of these processes. I will focus especially on three areas: (1) industry-university research cooperation, (2) research in and access to scientific computing, and (3) the engineering mission of the NSF. The Committee has the documents to which I will refer; we will be glad to provide copies to Committee members.

INDUSTRY-UNIVERSITY RESEARCH RELATIONSHIPS

The Board's annual report last year highlighted the growing importance to both universities and to industrial firms of industry-university research cooperation. The studies that lay behind that report have just been published and made available to you. They describe a dynamic situation with a rapid growth of scientific and engineering collaboration, driven by natural forces that will be good for both groups of institutions. Private industry looks to our research universities for trained people and for the results of fundamental research in science and engineering, both of which are essential to firms' abilities to innovate and increase their productivity. Cooperation between universities and industry is growing rapidly, and we hope our leadership, our report, and the studies recently published will contribute to an understanding of both the risks involved in such cooperation and the great potential benefits that it offers—to universities, to industry, and to the country as a whole.

The Foundation's early encouragement, beginning over a decade ago, has helped trigger industry-university research cooperation and continues to nurture it. For example, we have supported joint projects and centers for a number of years. In addition to these programs, this year's budget includes a major focus on making budget investments in several fields where university-industry relationships have the most immediate benefit to our economy—namely, engineering, materials science, and computing.

SCIENTIFIC COMPUTING

In scientific computing, the Board has encouraged the Foundation to respond both to the need to enhance access by research scientists to large-scale scientific computers and to support advanced research in new ideas for the design of high speed computers. Peter Lax, a Board member, brought these issues before the Board and headed a group sponsored by DOD and USF that prepared the "Report of the Panel on Large-Scale Computing in Science and Engineering." This report presented the need for making advanced computing resources available to the research communities. The Director then organized a series of internal studies which the Board reviewed and endorsed. They have led to an initiative in this budget to upgrade the access by scientists and engineers to large-scale computing.

THE ENGINEERING MISSION OF THE NSF

Let me review in somewhat greater detail what I believe to be one of our most important accomplishments during the past year—our policy guidance on the engineering mission of the NSF over the next decade. The Board brought several years work to a successful conclusion this past June. I believe the new directions will be strongly supported by the engineering community. The National Academy of Engineering, for example, provided us with many detailed ideas on how our policies could be implemented. Dr. White will, I'm sure, have more to say on that later.

Engineering and manufacturing processes have been transformed by the introduction of computers, telecommunications, and information management into every phase of the industrial environment for engineering and manufacturing. Engineering education and research capabilities in our universities must respond and adjust—a demanding task. The Board concluded that to meet the challenge to the Nation's engineering strength, and, therefore, to its economy and security, the National Science Foundation should expand and alter its traditional role in support of engineering sciences at academic institutions.

The Foundation is already taking important steps to deal with the development of engineering faculty and to upgrade university research instrumentation. In addition, the Board believes that:

(1) NSF should provide increased support for the engineering sciences to expand the frontiers of knowledge and practice and because of their importance to U.S. economic health and security. This should include a number of areas where little support is now provided, such as software engineering, magnetic technology, bioengineering, and plasma engineering.

(2) NSF should promote the appropriate use of computers in engineering education and research, address problems of availability and accessibility of software and

hardware, and increase its participation in advancing computer engineering and other areas fundamental to computer design and implementation;

(3) NSF should increase its support for research, education and training, and transfer of knowledge and technology between academe and industry in a variety of areas including engineering processed, materials processing, and manufacturing systems engineering;

(4) NSF should strengthen the base of academic engineering by encouraging faculty development and growth, providing suitable instrumentation and facilities, and improving educational and training methods and materials where needed.

These changed directions in NSF's engineering research and education programs will develop over the next few years. If successful, the Foundation can help our engineering schools produce graduates who are both more effective in research and better trained to enhance the Nation's productivity and competitiveness. We are excited at the prospect and urge you to help us pursue this opportunity.

NSF ACT AMENDMENT

Finally, I will touch on a proposed amendment to the NSF Act which has been submitted to you at the request of the Board. The amendment would treble the maximum dollar amount of awards for which the Board may delegate approval authority to the Director from \$2 million in total or \$500 thousand in any one year to \$6 million in total or \$1.5 million in any one year. We request this change to reflect inflation since 1968, the time at which the existing provision was enacted. The purpose of our request is to exercise more effective oversight over Foundation programs. By reducing the number of individual grants we are required to review based on a dollar limit, we will have more time to review overall programs and selected projects based on other equally important criteria. We will, for example, want to look in more depth at programs that are new initiatives or those that have special policy significance. I urge that you approve this amendment.

Mr. Chairman, during the past year the Board has dealt successfully with major issues that will have a significant impact on the Nation's scientific and technological future. We have developed an important level of consensus on these issues, clearing the way for effective action. The Director, with the support of the Administration, has moved expeditiously and strongly to implement these strategic directions for the National Science Foundation. We urge you and your members to support these directions.

Thank you for this opportunity to testify.
Attachment.

STATEMENT ON THE ENGINEERING MISSION OF THE NSF OVER THE NEXT DECADE AS ADOPTED BY THE NATIONAL SCIENCE BOARD

The United States is at a critical juncture in its industrial leadership. Not since Sputnik in 1957 has there been so much cause for concern about the adequacy of our science and technology base and our ability to capitalize on our scientific strengths to sustain industrial leadership. We face foreign competitors who have growing skills, lower costs, and higher productivity growth. These factors affect the security of our Nation, the standard of living of our people, and our legacy for future generations.

In view of the challenges to the Nation's technical competitiveness, the National Science Board has undertaken an examination of the Engineering Mission of the National Science Foundation for the next decade.

BACKGROUND

The scope of engineering

Engineering practice involves the application of engineering principles, experience, and training to the solution of specified problems and to the creation of useful articles, processes, and services. These principles come in large measure from research into the application of physics, chemistry, biology, and mathematics to products, processes, and services. Of special note are engineering and manufacturing processes, encompassing design, analysis, fabrication, conversion, assembly, testing, and risk assessment.

These processes have been transformed by the introduction of computers, telecommunications, and information management into every phase of the industrial environment for engineering and manufacturing. Soon these capabilities will be ubiquitous in any industry that expects to remain internationally competitive. For this reason, engineering education and research capacities in our universities must be

strengthened so as to match the capabilities and future needs of the public and private sectors. Computer and software engineering deserve special attention because of their great leverage across the entire spectrum of engineering activities.

Engineering research and education

Before World War II, engineering practice was principally based on accumulated experience, rules of thumb, and basic laws of science. The enormous success in applying science to engineering problems during World War II led to emphasis on science in engineering curricula, engineering research, and engineering practice. Knowledge bases and understanding of engineering problems advanced to greater sophistication than ever before in the history of the engineering profession. These advances have been strongly reflected in academic curricula and research.

Today, the further advances in engineering practice that have arisen from the dramatic impact of computers and information management on engineering and manufacturing processes need also to be fully incorporated into the academic scene.

The NSF role

From its inception, the National Science Foundation has had a responsibility for the Nation's health in engineering as well as in science. The private sector and other Governmental agencies play a major role in the support of total engineering research as they do in science. The NSF has a vital role to play in support of academic engineering research and in anticipating long-range research and education needs in proper balance with its role in the sciences and in relationship to the support of other agencies. In part, this role is stimulating and coordinating support for engineering from other agencies and the private sector.

There is a need to upgrade academic engineering facilities in the United States and to enrich the engineering curriculum. Specifically, more attention should be paid to engineering and manufacturing processes that have emerged from the dramatic advances of recent years. Additionally, there is a shortage of willing and qualified engineers to fill faculty positions in several areas of engineering.

CONCLUSIONS AND RECOMMENDATIONS

To meet these challenges to the Nation's engineering strength and, derivatively, to its economy and security, the National Science Foundation should expand and alter its traditional role in support of engineering sciences at academic institutions. The Foundation has already taken important steps to deal with the development of engineering faculty, to provide incentives for the increase of young faculty, and to upgrade university research equipment. In addition, the Foundation should design and establish cost-effective program activities in the four specific areas below.

The Foundation should not support the "clinical" practice of engineering; the development of specific products and solution of commercial problems should be left to the private sector. However, the linkage between the applications of engineering principles in industry and the research and teaching of our engineering schools should be close and mutually supportive. NSF policies should encourage this linkage.

In addition, the NSF should take full advantage of the willingness of the Federal Government's mission agencies to contribute their share of resources to strengthen basic engineering capabilities in our universities. To this end, the Foundation should seek ways to involve industry, professional societies, and other Federal agencies, as well as the academic community, in identifying priorities, and should develop its program in collaboration with these groups within the context of the efforts they are undertaking. At the same time, a broad-gauged, in-depth study should be made by the profession itself of the strengths and future directions of engineering research and education.

1. Investigator-initiated research in engineering sciences.—NSF has traditionally emphasized support of investigator-initiated research projects in the engineering sciences. Investigator-initiated research is essential for enhancement of engineering disciplines and expansion of frontiers of knowledge and practice. The Board believes that increased support is needed in the engineering sciences because of their importance to the economic health and security of the U.S. This should include areas where currently little or no support is provided: for example, software engineering, magnetic technology, bio-engineering, and plasma engineering (exclusive of fusion research).

The Board requests the NSF Director to develop a plan to increase NSF's role in the engineering sciences as appropriate, and in parallel to initiate a study of the full scope and status of engineering research, including its opportunities and needs.

2. Computational capabilities.—Great opportunities to enhance growth in productivity exist if the appropriate use of computers in handling engineering problems is facilitated. The computer is ubiquitous in modern engineering practice, as well as in engineering research. NSF can play a pivotal role in promoting progress in areas fundamental to new computational methods and in facilitating the appropriate use of computers in the engineering curriculum, as well as in research. In the case of large-scale computation, special efforts are needed to increase accessibility to computers and to provide training in their best use in engineering research.

Recognizing that several important studies are underway, the Board asks the Director to include plans: (a) to promote the appropriate use of computers in all phases of engineering education and research; (b) to address problems of availability and accessibility of appropriate software and hardware, including networking of computers; and (c) to participate more strongly in advancing the state and practice of computer engineering and other areas fundamental to computer design and implementation.

3. Engineering processes, materials processing, and manufacturing engineering.—Topics such as engineering design and analysis, materials processing, risk analysis, manufacturing engineering, testing, and quality control have not had an academic focus adequate to provide leading edge concepts and trained engineers to anticipate the Nation's future engineering needs, nor have they received appropriate support by NSF or other Federal agencies. Yet, advances in these areas are key elements in revitalizing U.S. technological competitiveness.

Toward this end, the director is asked to develop a program of activities (a) to increase the support of academic research in such area; (b) to improve the relevant training of engineers and modernizing of curricula; and (c) to promote the transfer of knowledge and technology in these areas between academe and industry. Because the universities can benefit so much from collaboration with private industry in these fields, we suggest that the Foundation examine carefully the appropriateness of using matching grants and encouraging industry-university cooperation.

4. Engineering faculty and research facilities.—The Board believes that training of engineers at the undergraduate level and beyond is impeded, severely in some cases, by shortages in qualified faculty and lack of up-to-date curricula, instructional and research equipment, and facilities. In contrast to the relatively weak position of academic institutions, industrial firms are able to attract the ablest researchers and provide them with the latest state-of-the-art equipment and laboratories. Strengthening the base of academic engineering is essential both for proper training of engineers and for optimal progress of engineering research. The NSF is in a unique position to determine the extent and nature of such impediments and to develop a suitable response.

Therefore, the Board requests that the Director examine these problems and provide a set of program activities involving measures (a) to encourage faculty development and growth; (b) to provide suitable instrumentation and facilities; and (c) to improve educational and training methods and materials in those situations where needed.

The Director should be guided, but not constrained, by the above recommendations.

Senator GORTON. Dr. Knapp.

Dr. KNAPP. Thank you.

Mr. Chairman, I now want to discuss one of the important activities in our budget request, the U.S. Antarctic program (USAP). Conducted by NSF as a national program, USAP and the national scientific research it supports are the principal expression of our Nation's presence in Antarctica and a requisite for the support of the Antarctic Treaty.

In 1985, we are requesting \$115.1 million for this program, an increase of \$12.6 million over fiscal year 1984. The Foundation has supported research in this continent since the 1950's. In fiscal year 1982, a Presidential directive consolidated funding and management responsibilities for the various Federal activities carried out in Antarctica under the National Science Foundation.

This role was reaffirmed in 1976 and again in February 1982, in a memorandum signed by President Reagan. This memorandum

recognized that these Antarctic responsibilities are over and above the normal activities of the NSF and directed that they should be supported accordingly.

The research supported in Antarctica increases knowledge of that continent, which constitutes fully 10 percent of the Earth's surface, and the surrounding stormy seas. Scientists conduct research at four locations, two coastal stations, one at the base of the Antarctic Peninsula, and one at the South Pole, which you saw earlier in the film. Scientists also conduct research aboard ships and through remote sensing techniques using satellites, aircraft, rockets, balloons, and unmanned stations.

The basic research in geology, geophysics, and oceanography performed in Antarctica improves our understanding of the resource potential of the continent and its significance in world weather patterns. The United States also conducts mapping and charting and operates weather observatories. It does ice forecasting there.

The Antarctic Policy Group, chaired by the Department of State, is responsible for providing policy guidance regarding program content. The Polar Research Board of the National Academy of Sciences provides continuing advice on scientific opportunities and priorities.

Senator GORTON. I would like to interrupt you with a question at this point while you are dealing with Antarctica. In the film that was shown, this was an international cooperative venture. What share of the scientific research which goes on in Antarctica is carried out by the United States through NSF, and what share is carried out by the other nations which participate?

Dr. KNAPP. I think I will have to submit the answer to that, in its exactness, to the record. My impression is that we carry on roughly one-quarter to one-third of the research, and the other nations are three-quarters to two-thirds, something of that nature.

[The material referred to follows:]

INTERNATIONAL COOPERATION IN ANTARCTICA

Fourteen nations maintain 37 year-round stations in Antarctica with some 880 personnel. During the austral summer operating season, the population expands to about 2400 persons, with the U.S. accounting for 1000 of the 1520 person increase. This is because U.S. air support allows us to transport large numbers of scientists quickly and easily, and to establish them at premier research locations virtually anywhere on the antarctic continent. Most other nations depend upon ship transport exclusively, and most confine their activities to areas very near their established stations. The participating scientists must either confine their work to the duration of the resupply ship visit, or must remain in Antarctica for a full year. Thus, while there were 78 foreign scientists accompanying all national programs last season, the U.S. program hosted 45 foreign exchange scientists.

While each nation's antarctic program is autonomous, there are a great many cooperative programs involving data collection and exchange, operation and maintenance of each others' instrumentation, and frequent sharing of logistic support. For example, the U.S. has profited from use of foreign ships for marine research otherwise not possible for us, and other nations have benefitted from support by our LC-130 aircraft. The nature of scientific research makes it very difficult to place any realistic value on the international effort, or to define the U.S. share of that total. Some indirect indications, however, might be: U.S. capital investments (stations, aircraft, ships) represent about 16 percent of the estimated total international investment in Antarctica; U.S. personnel in Antarctica represent about 42 percent of the total summer population; and scientific papers authored by U.S. scientists represent about 25 percent of all scientific papers published in the antarctic literature, and 70 percent of the classic (most often cited) scientific papers.

The nations presently active in Antarctica include Argentina, Australia, Brazil, Chile, Federal Republic of Germany, France, India, Japan, New Zealand, Poland, Republic of South Africa, Soviet Union, United Kingdom and the United States.

Senator GORTON. What other nations are involved?

Dr. KNAPP. Most of the European nations have a presence in Antarctica. I know just yesterday I discussed with some people of the Ocean Policy Group, which includes the Coast Guard, the NSF, the Coast and Geodetic Survey, NASA, and other agencies of the Government, the possible trip of a ship to Antarctica to do seismic studies of the sedimentary layers under the ocean just outside the ice on the continent, particularly to look for the possibility of structures which may contain oil or other resources of this kind.

Our ship is there now. There is a rather major German initiative which is finished, and also there is data from several other nations that is available, but not as available as our own. It complements our own data. The Soviet Union has a strong presence in Antarctica. The French have a presence. The British have a presence. And the countries nearby, particularly Chile and Argentina, would like to develop a considerably stronger presence in Antarctica than they have at the present time, and they are working in that direction.

Oh, yes, excuse me, the Japanese also. So we are not alone down there by any means, and we are certainly not dominating research on the continent.

Senator GORTON. Thank you. Pardon the interruption.

Dr. KNAPP. The naval support force provides primary logistics support for the program on a reimbursable basis. A private contractor operates South Pole, Siple, and Palmer Stations and performs all construction on the continent. The Department of Transportation, through the U.S. Coast Guard, provides icebreaker support to the program.

Finally, we continue to restore and replace obsolete facilities, particularly at McMurdo Station.

Mr. Chairman, I would like to focus my remaining remarks on a topic of great interest to this committee and to the Foundation, the ties between the universities and colleges and our Nation's industries. Dr. Massey has already described the Board's continuing interest in university-industry relations and in engineering and the Foundation's role in enhancing them. I would like to build on his remarks and tell you about some pertinent activities in our fiscal year 1985 request.

Mr. Chairman, our nation's universities are unique in that they produce both scientific and engineering knowledge and trained scientists and engineers. This trained manpower is the most important and closest link between our universities and our industrial enterprise. Foundation programs in 1985 will contribute directly to enhancing the quality of doctoral scientists and engineers produced by our universities and colleges in many ways.

We have increased support for graduate students on research award by 15.5 percent, to a total of \$103.4 million in fiscal year 1985. This firsthand experience performing scientific research tasks ensures excellent scientists and engineers in the future. Each of the centers of our new initiative for cross-disciplinary research will focus on a particular subject of national importance. Each will gen-

erally include participation of the companies or industrial associations in order to focus the research activities on technologically significant areas.

The rich cross-disciplinary research and learning environment of these centers will better prepare students for entering the multidisciplinary world of industrial practice. It also will give them first-hand exposure to the most advanced engineering research and technologies. On the research front, many of the Foundation's activities will continue to contribute directly to the vital link between our academic institutions and industry by increasing research support for basic work in critically important scientific and technical areas. I would like to describe some of these to you.

In 1981, we started a coordinated program for establishing a modern experimental university computer research capability. The purpose of this program was to help universities undertake improved long-range experimental work in this rapidly changing field. At the same time, this program created the research environment necessary to attract and retain the faculty and students so urgently needed in this industrially significant area.

In the everyday world, materials means concrete, lumber, and steel. In today's research world, the focus is on new materials, not occurring in nature, that can be fundamentally important to American industry. Research on these new materials often requires a team of scientists each with different skills and training in physics, chemistry, and engineering.

Since 1972, NSF has sponsored such interdisciplinary research through its materials research laboratories at 14 universities. A number of recently successful research projects illustrate the character of their work as well as the nature of their interactions with industry.

The Industry-University Cooperative Research Projects program is yet another activity which explicitly fosters joint research by academic and industrial scientists. The Foundation's Research Instrumentation Facilities program was established in 1978 to give academic, governmental, and industrial scientists access to expensive, sophisticated, specialized instrumentation such as lasers, nuclear magnetic resonance spectrometers, mass spectrometers, and electron microscopes.

In fiscal year 1985, there will be 14 of these regional facilities, located at universities across the United States. They will be supported at a level of \$3.8 million. Since 1973, the Foundation has provided support for the planning and operating phases of a number of industry-university cooperative research centers. We designed this activity to provide the seed money for establishing self-sustaining centers at universities which are supported by industry and emphasize research in areas that are responsive to industrial technical needs and university interests.

At present, 12 centers are operating with 120 faculty members, 18 postdoctorals, 195 graduate students, and 29 undergraduates. There are 173 industry memberships supported by 118 companies.

Since 1982 the Foundation has supported almost \$11 million; and matching funds from industry have equaled an estimated \$16 million. In 1984 State support is expected to total \$10 million.

Mr. Chairman, I believe that the National Science Foundation's programs have contributed and will continue to contribute to the long-term technological strength and economic competitiveness of the United States. We have a significant and long track record of encouraging, supporting and participating in the kind of university, industry and research linkages that are so vital to this long-term strength.

The administration's 1985 budget request for the Foundation builds upon this track record and proposes some new, exciting initiatives in astronomy, engineering, advanced computing, chemistry, materials, and biological processes, which will substantially enhance these efforts. I am pleased to recommend it to you and your committee this morning.

I will be pleased to answer any questions you now have along with Dr. Massey.

Senator GORTON. Dr. Knapp, your entire written statement will be included in the record.

This first series of questions are for you, or if Dr. Massey wishes to take the answer or supplement your answer we would be delighted to hear from him as well. First, relating to the internal management of the National Science Foundation, when do you plan to fill the longstanding vacancies for Assistant and Deputy Directors?

Dr. KNAPP. I, myself, and the White House are working as hard as we can to fill these vacancies. We have made some progress. We are expecting some nominations in, I hope, the near future, and we are continuing to discuss with the White House candidates for some of the other positions which are vacant and hope to have them filled as quickly as possible.

Senator GORTON. Do you plan to name a Deputy Director, now that you have created the position of Executive Assistant Director?

Dr. KNAPP. Absolutely, there will be a Deputy Director named.

Senator GORTON. Last year, you distributed throughout NSF the responsibility for making awards for special programs in international science and support for minorities and women. This committee had some reservations about that management change.

How have these programs fared as a result of that program's implementation?

Dr. KNAPP. I think they are faring very well. In the case of minorities, handicapped, and women, we have decided, after a lengthy study of the problems associated with total decentralization, to leave most of the programs in place in a specialized office within the Foundation, but to encourage the research directorates to expand their efforts on these minorities, women, and the handicapped programs.

We are in the process of doing that, and I think the programs are enhanced because of our approach. In the case of international science, we have decentralized, as we described. I think that we are coming along very, very well in our development of management tools to allow us to track very well the amount of money we are spending on international science.

We are, for the first time in the Foundation, understanding how much international science we really do, which is not only in the

international program of the Foundation, but also has been spread within the directorates for many years, but not labeled as such.

We are understanding the magnitude of this and the importance that international science has to the entire scientific enterprise. I think our programs will benefit greatly from this decentralization.

Dr. MASSEY. If I might add to that, this is part of the Board's oversight responsibility, to work with the Director on these kinds of activities, and the Board has worked with the Director in monitoring the effects of these changes. We do have various committees that are charged with looking at these areas, including a committee that deals with international science and one that deals with minorities and women. These committees work with the staff of the Foundation to report back to the Board periodically on the various activities in these areas.

From our point of view, I agree with the Director that this seems to be working in the way that he planned it. But it is the kind of thing the Board does watch as part of its oversight responsibilities.

Senator GORTON. Thank you.

I have already interrupted you, Dr. Knapp, with a question on the Antarctic program. I have several additional questions now. The budget request includes \$6 million, more than half of the increase in the budget for the operations support component of the Antarctic program, for reimbursement of the Department of Defense for military retirement costs.

Do these personnel spend their entire military careers in Antarctica?

Dr. KNAPP. Not their entire military careers, but the policy of the Defense Department, as it applies to all agencies who provide reimbursement for the military service, has been changed by the Congress to require that the military retirement pay, the contribution to the military retirement fund during the time of the employment of these people on stations, say in the Antarctic, be taken care of by the agency that is providing the funds for the military personnel.

Senator GORTON. So a particular military person spends 2 years out of a 20-year career in Antarctica, you are charged with one-tenth of the military retirement cost?

Dr. KNAPP. That is my understanding. It is only for the time in which that person is in service with the Antarctic support unit that the retirement portion of his pay is taken care of.

Perhaps Dr. Todd is here. He could say something or Dr. Bridgewater, who is the Acting Assistant Director for the Atmospheric, Earth and Ocean Sciences Directorate could speak to that.

Senator GORTON. Would you identify yourself.

Dr. BRIDGEWATER. My name is Albert Bridgewater. I am Acting Assistant Director for the Astronomical, Atmospheric, Earth, and Ocean Sciences, a very long title.

Last year, at the request of Congress, the military retirement pay computation was changed to pay for a fully funded system, and, as a result, each agency that uses military personnel must not only cover the base pay, but must also cover the retirement. So we will cover that portion for the time that they are used.

Senator GORTON. How many military personnel are used in any given year?

Dr. BRIDGEWATER. I would have to give the exact number for the record, but it is in the area of several hundred.

[The following was received for the record:]

MILITARY PERSONNEL SUPPORTING THE ANTARCTIC PROGRAM

The Department of Defense personnel supporting the Antarctic program are assigned to special units that perform no military missions. For this reason, all personnel costs associated with these organizations are reimbursed by the Foundation throughout the year, whether or not deployed to Antarctica. As of February 1984 these organizations include: Naval Support Force Antarctica (302), Naval Support Force Antarctica winter-over detachment (68), Naval Support Force Antarctica, Christchurch detachment (43) and Antarctic Development Squadron Six (393), for a total of 806 military personnel.

Senator GORTON. Thank you. That is all on that specific subject.

Doctor, how would you characterize the condition of the permanent facilities in Antarctica, particularly the stations at McMurdo and Palmer? What are your plans for these facilities?

Dr. KNAPP. The condition of these facilities is adequate, but they are deteriorating, as any facilities do in a harsh environment like the Antarctic. We plan to upgrade these facilities as rapidly as we can within the allotted funds that we have for the program. In particular, we are planning to construct a new storage shed at McMurdo this year.

I will provide for the record the details of our construction plan and our upgrading plans, but I know that we carry out a continual upgrading of these facilities and maintenance of these facilities. It is basically maintenance. We are not expanding the size of our operation in the Antarctic or the square footage of the buildings that we have.

[The following was received for the record:]

ANTARCTIC PROGRAM CONSTRUCTION AND UPGRADING

In 1977 we had our contractor develop an "urban renewal" program for orderly replacement or modernization of facilities in Antarctica. In the initial few years, many of the planned projects were stillborn when unforeseen circumstances pre-empted use of the necessary funds. In the last few years we have included a construction line item in our budget that has permitted substantial progress to be made on this ten year renewal program.

At McMurdo Station we have recently completed a new power plant. A contemporary replacement of the existing water plant using, in part, waste heat from the power plant is in construction. The building is erected, the equipment is on the site and completion is scheduled for the next austral summer. Our large equipment maintenance facility was destroyed by fire two years ago. Approval of the design concept for replacement has been obtained, the building site is being prepared, design and material procurement is being done this year.

Replacement and improvement of Palmer Station facilities, includes a new Aquarium System as well as storage and work spaces.

Senator GORTON. Thank you.

On the subject of science education, the National Science Board Commission recommended a massive 5-year training and retraining program for current math and science teachers, modeled after the institutes and workshops offered by NSF in the sixties and seventies. Has NSF conducted any studies to evaluate the overall effectiveness of these previous programs?

Dr. KNAPP. We have a number of studies on the effectiveness of those programs, which were done associated with each of the programs. There were some 28 programs in science education. Several

of those programs were associated with institutes for training, retraining, and those evaluations showed that these programs were very effective in their effect on the teachers who participated and who were retrained.

As you know, Mr. Chairman, we have just reinstituted the Directorate for Science and Engineering Education within the Foundation. We are evaluating what we can do with our funds for science education in 1984 and 1985. We have several pilot programs associated with institutes, honors workshops for teachers institutes, training systems, and the development of materials to facilitate training in the sciences.

It is too early to say exactly how our program will come into the Nation's school systems. However, the major thrust in our science education program this year is to institute programs which will have an impact on the entire education problem, if we possibly can, and particularly programs which are not directed just at the training of future scientists, but which make the teaching of science and technology easier to all the students who go to school. We are particularly expanding our programs that are concerned with materials for teaching at the elementary schools and junior high schools, trying to interest and teach very young people in science and engineering. This is something the Foundation has not done extensively in the past, and we hope to have very effective programs in this in the future.

Senator GORTON. Dr. Massey, do you have any comments on this?

Dr. MASSEY. Yes; there have been a number of studies, as Dr. Knapp said. But perhaps one of the most illuminating reviews of this program was done by the Commission itself. They have held a number of hearings, interviewed high school teachers who have participated in these programs, and the overwhelming anecdotal evidence that came out of those interviews was that the programs were indeed valuable. That is why they were recommending that some models of that type be used for the programs we are developing now in the Foundation.

Senator GORTON. Dr. Knapp, how is the VLBA radio telescope different from NASA's proposed space telescope?

Dr. KNAPP. They are really completely different instruments. They look at different things. They look at different signals from the heavens, from the stars. They are really for different purposes.

The space telescope is an optical telescope. It covers the optical wavelength range, in the visible, into a little bit of the infrared, a little bit into the ultraviolet. But it is primarily a space-based telescope like the telescopes at Palomar or other ground-based optical telescopes. It is used to look at the heavens with the visible light that the stars emit.

The VLBA is a radio telescope. It looks at radio emissions in the microwave region of the spectrum, a very different part of the electromagnetic spectrum which shows very different properties, very different images than the visible spectrum of the stars. It is quite different in the kind of information that is produced for astronomy.

Both are extremely important. The resolution of a radio astronomical telescope is absolutely incredible, much better than any possible optical telescope, because of the nature of radio emissions and radio detection.

Senator GORTON. Has there been enough cooperation or correspondence between NSF and NASA so that the two will complement one another closely?

Dr. KNAPP. The cooperation there is really excellent. We have astronomers who are funded by the NSF who are openly accepted for proposals to the NASA program for time for observation. They are then supported by NASA for that observation.

But there is no particular problem in the university community in general having access to either NSF instruments or NASA instruments. They mix very well.

Senator GORTON. Is the cost of the VLBA included in your instrumentation program?

Dr. KNAPP. No. That is a separate cost item in our budget.

Senator GORTON. Is the money required to purchase your advanced vector computer for the NCAR program coming out of your supercomputer fund?

Dr. KNAPP. That is also separately budgeted. The supercomputer fund is in addition to the VLBA.

Senator GORTON. Your budget justification says the NSF participates in international cooperative activities with some 30 countries. You request \$4.4 million for these activities, which is about \$147,000 per country. Are our foreign policy and international cooperation objectives met with sums like that? You must be doing a very efficient job.

Dr. KNAPP. The \$4.4 million is the funds which are used for workshops, for seminars, for getting people together to get the cooperative programs going. The funding of the science itself for the international programs is taken from the research directorates which would fund the particular kind of research that is being done.

This is the case of the distributed management that I spoke of earlier.

Senator GORTON. That is \$6.8 million?

Dr. KNAPP. The \$6.8 million is the science funded under direct bilateral agreements between two countries, the United States and another country. There is, in addition, a fairly large amount of money spent on science which has international characteristics, like tropical botanical studies in Brazil and a cooperative program in high energy physics with the European accelerator in Geneva, things of this kind. The number of dollars which are spent on science which has an international characteristic like that is more like \$40 to \$50 million a year from the Foundation.

Senator GORTON. Let us go back to the \$6.8 million. About how many different programs will be involved in that \$6.8 million appropriation?

Dr. KNAPP. Perhaps Mr. Green, the Director of that part of the Foundation, could answer it more accurately than I can.

Senator GORTON. Will you identify yourself for the record.

Mr. GREEN. I am Richard Green, Assistant Director for the STIA program.

The answer is fairly straightforward, Senator. Each of the research directorates in the Foundation will be involved with the program. Funds totaling \$6.8 million have been set aside in their budgets for supporting international bilateral programs.

Senator GORTON. I understand that, but how many different programs? How many different countries would be involved?

Mr. GREEN. 435 awards are planned in the program.

Senator GORTON. OK. Thank you.

NSF requested an additional \$500,000 for research in information technology. What specific areas of research will be emphasized in awarding grants under these programs?

Dr. KNAPP. Information science in its generality is supported by a much larger sum of money than the money that you just mentioned. It is supported in the computer research, it is supported in electrical engineering, it is supported in mathematics. It is supported in a number of places other than information science and technology, which is a program which is particularly directed toward the support of the transfer of information from, say, computers to humans, the provision of information such as scientific information to the scientists and others who have need for it, and programs associated with the transfer and storage of information of this kind.

Senator GORTON. How is research in artificial intelligence, such as vision and natural language, being coordinated with similar research support in other NSF programs, as well as with other Federal agencies?

Dr. KNAPP. Artificial intelligence work is supported in this program. It is also supported in the Computer Research Directorate, and it is coordinated by committee meetings, meetings of the appropriate program managers. I think coordination is quite reasonable.

Senator GORTON. Does that coordination extend outside of NSF both to other Federal agencies and to the private sector, as well as within NSF?

Dr. KNAPP. Yes, it does, sir. In particular, the Defense Advanced Research Projects Agency, DARPA, has a major program in artificial intelligence being funded last year and this year and continuing, and we have quite close ties with a number of things that are going on there.

Senator GORTON. How about the private sector?

Dr. KNAPP. I am not exactly certain of the mechanism. Perhaps Dr. Wilson could speak on that.

Dr. WILSON. This is done basically on an informal basis. Our program offices know what is going on in the private sector, and it is through people from the private sector in the advisory committees that we get the main report.

Senator GORTON. Dr. Wilson, this may be for you as well as for Dr. Knapp. One more question on the same subject. What about foreign governments? Is there any exchange of research data in this field with other nations?

Dr. KNAPP. There is certainly an exchange of data on an informal scientist-to-scientist basis with other governments, other scientists in other countries. I do not know of any formal committee arrangements which produce a data interchange of this kind.

Dr. Wilson, do you have a comment on that?

Dr. WILSON. No; I know of none.

Senator GORTON. A great deal has been written about the value of information in an economy increasingly reliant on information services and products. What have been the results of NSF research

in the information impact program in understanding and quantifying the economic properties of information?

Dr. KNAPP. I will have to ask one of my Assistant Directors to respond to that question. Dr. Rabin, is that in your Directorate?

Senator GORTON. I would appreciate it if you would identify your name and position.

Dr. RABIN. My name is Robert Rabin. I am Acting Assistant Director for Biological, Behavior and Social Sciences. The Information Sciences Division is within our Directorate.

The information impact program has been a small program for several years. It is growing to the degree that we now feel that, as an economic commodity, it should have a stronger role to play. We have been looking into a variety of means and funding a variety of programs that examine that impact by way of linkages, networking, for certain specific topics.

It is our belief, at the present time, from such linking and networking studies examining information as an economic commodity, that it certainly has made a strong impact in local areas, in the areas that we have looked at, in some States and regions. We can supply specific examples for the record, but so far we have been very pleased with the results of that linkage between private industry and university researchers.

Senator GORTON. Does NSF coordinate with OMB's oversight of research management activities in Federal agencies?

Dr. ROBIN. I am not personally aware of that.

Senator GORTON. That answer can be submitted for the record if you wish.

[The material referred to follows:]

NSF INFORMATION TECHNOLOGY SYSTEMS

The activities of NSF information technology systems are closely coordinated with OMB. These systems generally involve automatic data processing and consist of:

General administrative operations with emphasis on grants management, financial control, and management information conducted in-house in Washington, D.C.; and

Instrument control, data gathering, data reduction and analysis for scientific programs, as well as general administrative functions at five NSF-owned national astronomy centers and the National Center for Atmospheric Research (NCAR).

NSF submits a report to OMB annually concerning its requirements for information technology systems. This report provides estimates for capital investments, personnel, equipment, rental space, and commercial services.

Senator GORTON. Thank you.

For fiscal year 1985, the National Academy of Sciences/National Research Council proposed an increased emphasis on development and application of the techniques of chemistry to the solution of molecular-level problems in life processes, and funding for research in chemical reactivity and chemical catalysis.

I understand that this research has implications for our national leadership in biotechnology and applied biology. How does the increase in funding compare to the levels suggested by the National Academy of Sciences? I take it it is less.

Dr. KNAPP. I do not, again, know those figures directly. I do know that we have a major new initiative in the National Science Foundation for 1985 in biotechnology and the chemistry of life processes, which is a joint program between the chemistry division

of the mathematical and physical sciences directorate and the biology division of the BBS directorate.

That level of funding is \$10 or \$12 million for 1985. I would imagine that the request for this funding from the National Academy study would be considerably more than that.

I believe that the \$10 million, if that is the correct number, and I think it is, is a good level at which to start and build a program and will get us a good start on getting research in this cross-disciplinary area going.

Senator GORTON. Thank you.

Dr. Massey, in your statement you recommended an amendment to the NSF Act which would allow the Board to exercise more effective oversight of NSF programs. Would you comment on just how that oversight would be improved?

Dr. MASSEY. Yes; as of now, the Board is required to approve grants of a certain size, of a certain commitment—individual grants of \$500,000 for 1 year and total grants of \$2 million or more. The disciplinary fields in the NSF are such that the size of the grants vary considerably. In some directorates, such as astronomical, atmospheric, Earth, and ocean sciences, grants tend to be very large. In biological, behavioral, and social sciences, or in theoretical physics, the grants tend to be smaller.

Because of this requirement, the Board does not feel it has sufficient flexibility to review grants over the whole spectrum of activities, because we have to look at the very large grants and we may delegate smaller grants.

Senator GORTON. That is where you are hampered in a broad review.

Dr. MASSEY. That is right. Just given the time requirements the Board has, meeting once a month for 2 days, we simply do not have the time now. Also, there are new fields such as biotechnology. The grants in any new areas tend to be small when they start out, and the Board would like to spend more time looking at new initiatives rather than reviewing routine, continuing grants simply because they have passed the dollar scale of \$500,000.

And as I said in my testimony, that has not changed since the late sixties. Inflation has moved the level of grants up.

Senator GORTON. Could you now describe for me the process the Board uses to formulate issues for its annual meeting in June and perhaps give us some insight into the issues you will focus on in this year's meeting.

Dr. MASSEY. I will answer the last part of the question first because it relates to the question the Director just answered. One issue this year is biotechnology and the role the NSF should play in support of research in that field.

The other issue this year in the June meeting will be what has been called the infrastructure of science: the human resources needed, the instruments needed, the equipment, buildings, technical support, the underlying structure; and how that should be supported and the need for making that healthy.

We have a year-long planning process. The Board has a Committee on Planning and Policy, which I chair. We also have what we call minigroups, groups of Board members, of three or four each, that work throughout the year with each Assistant Director. These

groups of Board members then, formally and in conjunction with the staff of NSF, make plans, long-range plans, for a 4- or 5-year cycle.

These are discussed at various meetings throughout the year, culminating, in January and February, with a major planning session with the Board, followed by a statement of the Director that encapsulates and encompasses the entire process. We just finished that at our meeting last month.

Out of that meeting in February, we plan for the June planning session. That usually leads to a major policy statement, which we then ask the Director to implement. Last year's planning issues were on engineering, and that led to this engineering initiative, and on science education, which followed the Commission's report, and that led to new initiatives in science education.

Senator GORTON. Thank you.

I am going to ask questions on engineering initiatives after Dr. White delivers his formal testimony.

Dr. White, if you will come forward now.

I am told, Dr. Massey, that you need to leave by 10:45, and I wish to take this opportunity to thank you for all of your help.

Dr. MASSEY. I apologize, and thank you very much.

Senator GORTON. Dr. White.

Doctor, your entire written testimony will be included in the record.

STATEMENT OF DR. ROBERT WHITE, PRESIDENT, NATIONAL ACADEMY OF ENGINEERING

Dr. WHITE. Thank you, Mr. Chairman. I appreciate the opportunity to present my views on the engineering programs of the NSF.

The Academy of Engineering strongly believes that it is important to strengthen engineering at the National Science Foundation and has given its recommendations on this matter to the Foundation in two reports, one entitled "Strengthening Engineering in the National Science Foundation," which we submitted last July, and a more recent report entitled "Guidelines for Engineering Research Centers" about which you heard from the Director, which we are releasing today publicly and which I will discuss later in my testimony.

With your permission, I would like to submit both of these reports—they are brief—for the record.

Senator GORTON. They will be included in the record.¹

Dr. WHITE. It is our view that the time for action to strengthen engineering in the National Science Foundation is propitious given the national need to maintain U.S. industrial competitiveness and productivity.

The industrial challenge to the United States from other nations is in part an engineering and technological challenge. It is the National Academy of Engineering's view that engineering education and research are key elements in meeting that challenge. We need to produce engineering graduates in the diversity, quality, and

¹ The reports have been retained in committee files.

quantity required by industry and Government to maintain our technological leadership.

The support for research and education in engineering is the mission of the National Science Foundation, and our universities look to the NSF for that support. We do, however, need to put the NSF role in engineering in proper perspective. The NSF is but one player in the Federal Government that supports and fosters engineering activities. The Federal Government is but one force at work in the country. Industry and other parts of the private sector, as well as State governments, are all significant players. Some statistics bring this home clearly.

The National Science Foundation provides only 13 percent of all on-campus engineering R&D support at doctorate-granting institutions. The proposed Foundation budget for engineering activities for fiscal year 1985 is \$147 million.

Although the NSF is a minor player in terms of its budget, it is a major and indispensable element in sustaining the health of the engineering research and the educational enterprise. That is the principal source of funds for fundamental research, for engineering research in our universities which provides the essential environment for attracting and holding good faculty and for student education. It is this vital role that gives our investment in NSF engineering activities such great importance. It is an investment with enormous leverage in determining the quality of the entire national engineering enterprise.

The Academy has urged the strengthening of NSF's traditional admissions in engineering research and education. There is a need to insure that individual investigators and the disciplinary base of engineering are adequately supported. However, we have also urged that our long-term industrial outlook requires that support of a class of engineering activities that are multidisciplinary in nature directly address major national technology problems, and that these might represent new and innovative areas for emphasis by the National Science Foundation.

The Academy's views are similar to those expressed in the recent policy statement of the National Science Board, which Dr. Massey has discussed, affirming the need to strengthen engineering in the National Science Foundation. The present fiscal year 1985 budget also indicates that a decision has been made to implement that NSB policy and provide increased support for engineering activities.

While the increases proposed—some 22 percent of the fiscal year 1984 appropriations—are substantial, it should also be recognized at the outset that the increased amount being sought does not address all the needs of engineering research and education in our universities. However, the new directions and strengthened programs are most welcome and deserve the full support of the Congress.

Let me comment on some of the recommendations we have made to the National Science Foundation and the manner in which the Foundation has responded. Our examination of NSF activities indicates that there has been a virtual decrease in the dollar amount of grants supporting individual investigators. This has resulted in engineering research in universities becoming more analytic and

thus experimental. We have recommended that a better balance between analytic and experimental research supported by the National Science Foundation would be a desirable goal.

The National Science Foundation is now planning to invest great amounts of money in instrumentation, equipment and competition support, as well as increasing the average size of grants. These are important steps, even though the total amount available for individual investigators still falls short of what is needed.

We have advised the National Science Foundation that there is a need for funding research and education across disciplinary engineering, such as in manufacturing systems. A major initiative of the NSF in the fiscal year 1985 budget is the proposal to initiate a new kind of cross-disciplinary research centers in universities whose mission would be focused on both research and education problems basic to our industrial needs.

The Foundation has asked the National Academy of Engineering for its advice on the structure, organization and funding of such matters. I would like to summarize briefly the conclusions of that report.

The Academy of Engineering believes that this engineering research center initiative can fill an important gap in engineering education and research in a novel and innovative way. It offers the opportunity for closer interaction between universities and industry and can provide undergraduate and graduate students with hands-on engineering education now difficult to obtain in universities.

If the program is properly funded and designed, it can significantly increase the number of engineering graduates, and above all, be a program in which the National Science Foundation can focus on major engineering problems of importance in maintaining our industrial competitiveness.

This initiative represents a development which can have a major impact on both engineering education and research in the universities in collaboration with industry. I should caution, however, that in our view the fiscal year 1985 plans must be regarded only as a beginning of the program. To be effective, the program must grow and be sustained over the years ahead. We see the program eventually supporting as many as 25 multidisciplinary engineering research centers, each at a steady State level of \$2.5 to \$5 million, not including costs of student stipends and tuitions. The program should be designed to affect about 10 percent of the engineering students at the institutions having such centers if it is to have the kind of impact that is necessary.

We see the program building up over a 5-year period with perhaps 5 to 10 centers being initiated this year. The planned centers will provide important new educational facilities, equipment for undergraduate engineering instruction, and support for certain large-scale engineering and research activities not accessible in other ways to the university community.

The proposal represents a useful initiative in improving interaction with industry, the focus of most engineering development and practice, and of signaling an intent on the part of the National Science Foundation of asserting a leadership role and a support of engineering research.

We believe that if the National Science Foundation can continue to sustain the growth of engineering in future years as it has in this fiscal year 1985 budget, it can become the focus for a strengthened engineering education and research that the Nation needs and that we, the Academy, believe is warranted.

We hope that this committee and the Congress will view these developments in the National Science Foundation as much as we do an important investment in the future health of the engineering enterprise in this country and the Nation's ability to be productive and competitive in an increasingly competitive world.

Thank you, Mr. Chairman.

I would be delighted to answer any questions.

[The statement follows:]

STATEMENT OF DR. ROBERT M. WHITE, PRESIDENT, NATIONAL ACADEMY OF
ENGINEERING

I welcome the opportunity to present my views on the engineering programs of the National Science Foundation. The National Academy of Engineering strongly believes that it is important to strengthen engineering in the NSF, and has given its recommendations on this matter to the NSF in a report entitled "Strengthening Engineering in the National Science Foundation" submitted last July, and in a more recent report entitled "Guidelines for Engineering Research Centers" which we are publicly releasing today, and which I will discuss later in my testimony. With your permission, I would like to submit copies for the record.

The time for action to strengthen engineering in the National Science Foundation is propitious given the national need to maintain U.S. industrial competitiveness and productivity. The industrial challenge to the United States from other nations is in part an engineering and technological challenge. It is the National Academy of Engineering's view that engineering education and research are key elements in meeting that challenge. We need to produce engineering graduates in the diversity, quality, and quantity required by industry and government to maintain our technological leadership. The support for research and education in engineering is the mission of the National Science Foundation, and our universities look to the NSF for that support.

We do, however, need to put the NSF role in engineering in proper perspective. The NSF is but one player in the federal government that supports and fosters engineering activities. The federal government is but one force at work in the country. Industry and other parts of the private sector as well as state governments are all significant players. Some statistics bring this home clearly. The NSF provides only 13 percent of all on-campus engineering R&D support at doctrine granting institutions. The proposed NSF budget for engineering activities in fiscal year 1985 is \$147 million.

Although the NSF is a minor player in terms of its budget, it is a major and indispensable element in sustaining the health of the engineering research and the educational enterprise. It is the principal source of funds for fundamental engineering research in our universities which provides the essential environment for attracting and holding good faculty and for student education. It is the vital role that gives our investment in NSF engineering activities such great importance. It is an investment with enormous leverage in determining the quality of the entire national enterprise.

The Academy has urged the strengthening of NSF's traditional missions in engineering research and education. There is a need to insure that individual investigators and disciplinary base of engineering are adequately supported. However, we have also urged that our long-term industrial outlook requires the support of a class of engineering activities that are multi-disciplinary in nature, directly addressing major technology problems, and that these might represent new and innovative areas for emphasis by the National Science Foundation.

The Academy's views are similar to those expressed in the recent policy statement of the National Board affirming the need to strengthen engineering in the NSF. The President's fiscal year 1985 budget also indicates that a decision has been made to implement the NSB policy and provide increased support for engineering activities. While the increases proposed—some 22 percent above the fiscal year 1984 appropriations—are substantial, it should also be recognized at the outset that the increased amount being sought does not address all the needs of engineering re-

search and education in our universities. However, the new directions and strengthened programs are most welcome and deserve the full support of the Congress.

Let me comment on some of the recommendations we have made to the National Science Foundation and the manner in which the Foundation has responded. Our examination of NSF engineering activities indicated that there has been a gradual decrease in the dollar amount of grants supporting individual investigators. This has resulted in engineering research in universities becoming more analytic and less experimental. We recommended that a better balance between analytic and experimental research supported by the National Science Foundation would be a desirable goal. The National Science Foundation is now planning to invest greater amounts of money in instrumentation, equipment, and computational support as well as increasing the average size of grants. These are important steps, even though the total amount available for individual investigators still falls short of what is needed.

We have advised the National Science Foundation that there is a need for new approaches to funding research and education in cross-disciplinary engineering, such as in manufacturing systems. A major initiative of the National Science Foundation in the fiscal year 1985 budget is the proposal to initiate a new kind of cross-disciplinary Engineering Research Centers in universities whose mission would be focused on both research and education problems basic to our industrial needs. The Foundation has asked the National Academy of Engineering for its advice on the structure, organization, and funding of such Centers. I would like to summarize briefly the conclusions of that NAE report.

The NAE believes that this Engineering Research Center initiative can fill an important gap in engineering education and research in a novel and innovative way. It offers the opportunity for closer interaction between universities and industry can provide undergraduate and graduate students with hands-on engineering education now difficult to obtain in universities. If the program is properly funded and designed, it can significantly increase the number of engineering graduates, and above all, be a program in which the National Science Foundation can focus on major engineering problems of importance in maintaining our industrial competitiveness. This initiative represents a development which can have a major impact on both engineering education and research in the universities in collaboration with industry. I should caution, however, that in our view, the fiscal year 1985 plans must be regarded only as a beginning of the program. To be effective, the program must grow and be sustained over the years ahead. We see the program eventually supporting as many as 25 multidisciplinary Engineering Research Centers each at a steady state level of \$2.5-\$5.0 million not including costs of student stipends and tuitions. The program should be designed to affect about 10 percent of the engineering students at the institutions having such Centers if it is to have the kind of impact that is necessary. We see the program building up over a five-year period with perhaps 5-10 centers being initiated this year.

The planned Centers will provide important new educational facilities, equipment for undergraduate engineering instruction and support for certain large-scale engineering research activities not accessible in other ways to university community. The proposal represents a useful initiative in improving interaction with industry, the focus of most engineering development and practice, and of signaling an intent on the part of the National Science Foundation of asserting a leadership role in the support of engineering research.

We believe that if the National Science Foundation can continue to sustain the growth of engineering in future years as it has in fiscal year 1985, it can become the focus for strengthened engineering education and research that the nation needs and the NAE believes is warranted. We hope that this Committee and the Congress will view these developments in the National Science Foundation much as we do—an important investment in the future health of the engineering enterprise in this country, and the nation's ability to be productive and competitive in an increasingly competitive world.

Senator GORTON. Thank you.

I will start with some questions for Dr. Knapp. Would you describe how the NSF fiscal year 1985 plans for engineering converge with or diverge from the recommendations that the National Science Board made in its 1983 policy statement, recommending that NSF engineering activities receive new direction and emphasis?

Dr. KNAPP. The program that we are putting forward responds to that study in almost all of its details; we have a very good overlap

with respect to the Board's recommendation and also with respect to the recommendations of the Academy, which you have just heard.

I believe we are responsive to the Board's study, and I think that this will be a good start on a program which, as Dr. White just mentioned, can grow and which will support academic engineering at a very productive level over the next few years.

Senator GORTON. How does the Foundation's program to establish 10 multidisciplinary engineering centers differ from, let us say, the industry-university cooperative research center program and the materials research labs? Are their goals not similar?

Dr. KNAPP. They are similar, but not the same. The industry-university cooperative research center program is a program where the NSF provides seed money to a university which then gets support also from industry as a requirement. The NSF backs away each year with a smaller amount of money. At the end of 5 years, it is an industry-university research center with its entire support coming from the industrial sector. This is not a requirement for the engineering centers.

The materials research laboratories are different in that they are not multidisciplinary between engineering disciplines. They are really multidisciplinary across a wide variety of fields, including physics, chemistry, engineering, a very broad spectrum of disciplines within the university.

However, the focus and the model for the engineering center is, in some sense, the MRL—not exactly, but it is the ideal we were going for when we designed them. The materials research laboratories are very successful centers. They are slightly different from the engineering centers, but they are the model that we used to design the engineering centers.

Senator GORTON. What kinds of research are likely to be the focus of these engineering centers, and how is industry going to participate?

Dr. KNAPP. The kind of research will be fundamental research on things such as manufacturing engineering, robotics, things which in general require the input of engineers from different disciplines such as electrical engineering, mechanical engineering and so on, in order to carry out the mission. They will be more fundamental in the sense of the kind of knowledge that is strived for than direct industrial research would be.

So that, for example, in the case of robotics, a center would perhaps look at the very fundamental issue of how do you recognize a part in a television screen, and how would that robot go about picking up that part, where in an industrial university center the specific design of hardware which could do that would be studied.

It is perhaps a complicated nuance, but it is a level of abstraction and a level of the sort of fundamental nature of the information which is being sought.

Perhaps Dr. White could comment.

Dr. White.

Dr. WHITE. Modern industrial functions require, for their successful development and prosecution, the participation of people from many different disciplines. You can go down a variety of industrial functions, whether it is communications or manufacturing, and ask

yourself what would it take to develop various components of that communication or manufacturing system and put it into being. Raw materials processing has been mentioned or transportation. If you focus on the major industrial functions that have to be undertaken, then you begin to get some ideas of the foci for some of these engineering research centers; and in order to do the research on them, you would have to bring together engineers from different disciplines to address these questions.

Senator GORTON. Is there any cooperation between NSF and the Bureau of Standards in connection with NBS research on automated manufacturing or robotics?

Dr. KNAPP. The sort of work that we do is different from that which the National Bureau of Standards does, but, yes, there is cooperation. We have a good connection between the NSF staff and the NBS staff. In fact, we have a man from the management of the NBS spending a year away from the NBS at the NSF right now.

Senator GORTON. As you know, a number of members of the subcommittee, the chairman included, introduced a bill last year to establish a manufacturing science and technology research program in order to improve the productivity of manufacturing methods and processes. In what ways do the engineering centers or other NSF activities relate to this issue?

Dr. KNAPP. I think there is quite a bit of overlap between the objectives of the program discussed in your bill and what we are proposing to do with our engineering centers and what we have done with the support of engineering in universities from the NSF in the past. It is not exactly the same, but it is certainly the same goal.

Dr. WHITE. Yes. They would be directly related, Mr. Chairman. If one is looking at manufacturing systems, these engineering research centers are envisioned, at least in our view, as being ventures which are jointly undertaken by universities and by industries. They would focus on activities such as manufacturing systems. In the process you would be educating students at both the undergraduate and the graduate level on how to deal with modern manufacturing systems. You would also be doing some research on manufacturing systems. We envision the people from industry directly involved in such manufacturing systems research with the academic community in these engineering research centers.

Senator GORTON. Does this NSF initiative make that bill irrelevant or duplicative?

Dr. KNAPP. I am not completely familiar with all of the details of the bill, since the bill was associated with the Department of Commerce, and I imagine the Bureau of Standards who had been a player in that whole legislation.

Senator GORTON. I would appreciate your looking at it then and sending us your comments on whether you are doing everything we proposed in that bill.

Dr. KNAPP. We are certainly not doing everything proposed in terms of the magnitude of the program at the present time.

[The following was received for the record:]

COMPARISON OF S. 1286 AND NSF ENGINEERING INITIATIVE

The goals of S. 1286 and the NSF engineering initiative are quite similar, but there are some differences. These are listed below:

The S. 1286 programs include four basic components: grants; centers; utilization of research; and competitiveness studies. Each is administered by the Department of Commerce. The NSF initiative does not include the technology utilization or competitiveness study aspects.

Grants and centers in S. 1286 are limited to research on methods of producing more efficient manufacturing processes and methods. The NSF program is not so limited.

The NSF centers would be at universities in order to more directly insure the strengthening of engineering schools and the improved training of graduate and undergraduate students.

The NSF program strongly encourages but does not require matching support for its centers. Both require industry participation of some kind, such as assignment of personnel.

In short, the NSF program is more flexible and less directed both in methods and scope of activities which can be funded in grants and centers. This is appropriate to the NSF role of responding to unsolicited, investigator-initiated proposals.

Senator GORTON. On crosscutting issues facing the Foundation, such as the engineering centers, supercomputers, and instrumentation, do you believe that NSF is structurally organized to address effectively these important science policy issues, or will organizational changes be appropriate?

Dr. KNAPP. We are considering organizational changes for the cross-disciplinary computer research initiative, where we have an office reporting to the Director for coordinating this between the various directorates. I must say that the NSF reflects the organization of the universities which it funds in the sense of having the directorates organized along disciplinary lines, which are the same as university disciplines. In that sense we structurally represent the universities, and we can expect that the coordination—for example, the computer initiative in universities—will be different and will require some structural changes within universities in order to carry this out.

We expect to make an organizational change to accomplish this task within the Foundation, an office which reports to the Director. As far as the engineering centers are concerned, no organizational changes will be needed. There is an engineering directorate within the Foundation at the present time, and they will coordinate this program.

Senator GORTON. On this general subject, what do each of you think of the proposals to change the NSF organic act—name, number of board members, charter and so on—to emphasize the importance of its engineering activities?

Dr. KNAPP. I think that we are emphasizing the importance of the engineering activities of the Foundation, and our actions speak quite well to engineering. I do not think it is necessary to change the organic act at this time. I think some of the provisions in that proposed legislation would make the management of the Foundation more difficult.

Senator GORTON. Dr. White.

Dr. WHITE. As our reports indicate, we are very much interested in whatever can be done to strengthen engineering in the National Science Foundation. Whether this requires major or minor changes in the statute is something we have to look at. I have not looked at

the details or the implications of the changes proposed in the bill recently introduced by Representative Brown in the House. I presume that is the bill you are referring to.

Senator GORTON. Yes.

Dr. WHITE. I have seen the bill. We have not analyzed its impact, so I am not in a position to indicate.

Senator GORTON. You will have a comment at some later time, I assume.

Dr. WHITE. At some later time the Academy will be taking a closer look at that, yes.

Senator GORTON. The National Academy of Engineering's report entitled "Strengthening Engineering in the National Science Foundation" recommended that NSF employ more engineers in order to develop more widespread understanding of engineering at NSF and to give proposals in engineering a better chance to be funded.

Starting with you, Dr. Knapp, I would appreciate the response of each of you to that recommendation.

Dr. KNAPP. That has several different implications. We can start by looking at the membership of the National Science Board, which is the body which oversees the operation of the Foundation. I think, at last count, there are seven or eight engineers or industrial scientists on the Board at the present time. That is a fairly large fraction and, I think, very representative of the kinds of programs that we have in the Foundation right now.

I think engineering is very well represented on the National Science Board and we have had an Engineering Directorate since 1981. We are moving very rapidly with our engineering programs.

We have had a decreasing overall staff for the Foundation during that period of time. We have some very capable engineers on the staff of the Foundation and within the Engineering Directorate. The number is growing as we can add new people to the staff.

Senator GORTON. Dr. White.

Dr. WHITE. The comment in our report means exactly what it says, Mr. Chairman.

Senator GORTON. You cannot improve on the writing.

Dr. WHITE. I believe the NSF is moving in the direction of our recommendation. We want to see more people with an engineering background at all levels in the Foundation, on the National Science Board, on the advisory committees, on the panels that review proposals, and among the presidential appointees. I have to say with Dr. Knapp, that things seem to be moving in the right direction at the present time. We intend to keep up the pressure.

Senator GORTON. Dr. White, how was the engineering community consulted during the development of NSF's engineering initiatives?

Dr. WHITE. There are many ways in which the engineering community is consulted. I can only address how the members of the Academy who are members of the engineering community were consulted. The reports which you have before you, indicate the membership of the panels that prepared them. You will find that the membership is made up of individuals with outstanding accomplishment in engineering. They come both from industry and academia and from many different engineering disciplines. That is the traditional way in which the Academy consults with and bring in

members of the engineering community—to produce reports such as those I have presented to you.

In the case of both reports we believe we have brought together a quite representative group of outstanding people from both universities and industry to work on and give a lot of time and thought to the recommendations embodied in these reports. That is our principal method.

Now, the Academy of Engineering also does consult with various representatives of professional societies. We meet a couple of times a year to discuss problems of common interest. So there is a loose consultation that goes on all year. However, our principal mode is bringing in individual members of the community to work with us on these panels.

Senator GORTON. I would like to thank both of you, as well as Dr. Massey, who has already had to leave, for the great help you have provided us this morning.

With that, the meeting is adjourned.

[Whereupon, at 11:05 a.m., the hearing was adjourned.]

NATIONAL SCIENCE FOUNDATION AUTHORIZATION

THURSDAY, FEBRUARY 23, 1984

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:05 a.m., in room SR-253, Russell Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORTON

Senator GORTON. The committee will come to order.

Welcome to the second day of our hearings on the proposed budget for 1985 for the National Science Foundation. At our hearing yesterday we heard a comprehensive overview of the fiscal year 1985 budget from Dr. Knapp. We also heard testimony and discussion on major new engineering initiatives and existing university cooperative programs from Dr. Walter Massey and Dr. Robert White.

Today the hearing will focus again on areas which are of keen interest to the members of the subcommittee. Indeed, the subjects we will cover today may well be crucial to our Nation's ability to be productive, innovative, and to compete effectively abroad.

The deterioration and obsolescence of research instrumentation in our Nation's universities has been well documented by reports from the National Science Foundation and others. Yet state-of-the-art instrumentation is essential for progress and experimental research.

Advanced computers are another specialized area of need within research instrumentation. I will be interested today to hear reactions to the recent articles about Japanese development of supercomputers and the implications of Japanese competition in the world's supercomputer market.

We will begin by hearing from Dr. George A. Keyworth on the administration's priorities and particular interests in the 1985 budget for the National Science Foundation. Then the remainder of the hearing will focus on research instrumentation issues, including supercomputers. We will hear from Dr. Edward Knapp, Dr. Neal Lane, Chairman of the NSF Advisory Committee on Supercomputers and chairman of the physics department at Rice University, and Dr. Richard Zdanis, chairman of the multiagency project,

who will assess alternative approaches to meeting university research, equipment needs.

Senator Heflin has an opening statement.

OPENING STATEMENT BY SENATOR HEFLIN

Senator HEFLIN. Mr. Chairman, today we continue hearings on the fiscal year 1985 budget request for the National Science Foundation. The more opportunity I have to learn about the NSF, the more impressed I am with the important role they play in advancing American science and engineering.

For fiscal year 1985, the President has requested a total research and development budget of \$53 billion. This budget is split 65 percent for defense R&D and 35 percent for civilian R&D. I have been supportive of the administration's efforts to strengthen our national security and, therefore, see the merit of boosting our defense R&D.

However, while defense R&D increases by 23 percent over fiscal year 1984, the civilian R&D budget shows less than 1 percent growth overall. This doesn't keep up with inflation. There are many needs in our economy where R&D can contribute significantly, and I do want to make sure we don't overlook some key investments in our future. That is why the NSF budget is so important.

In many respects the NSF represents our Federal "balance wheel." It adjusts and balances national needs with the ability of our mission agencies to support those needs. Where there are gaps, particularly in the civilian area, the NSF can step in and fund needed research.

There is a second area where the NSF plays a crucial role. With its heavy emphasis upon basic research, the NSF is a vital source of R&D resources for our universities and colleges. I support our increases in basic research.

Recently, I had an occasion to learn about another important role the NSF plays, that is in getting universities and industry to work cooperatively. In hearings held in Alabama on December 6 and 7, this subcommittee gathered testimony on the importance of R&D to our economy. We heard from quite a broad set of witnesses on how universities, industry, and government can work cooperatively. At those hearings NSF described its cooperative R&D programs. It was an excellent presentation. We also looked at the role of research parks, and we received wide support for the Chairman's bill, S. 1286 dealing with manufacturing R&D.

Mr. Chairman, there is one final aspect of the NSF budget that I know you and I have a common interest in and that is their education programs. While the focus of our hearings will be primarily on NSF's research activities, no one should have any doubt about the importance of NSF's science, math, and engineering education efforts.

The NSF budget of \$1.5 billion for fiscal year 1985 is a good one for our science and engineering community. Its 14 percent increase this year, coupled with last year's increase, should provide needed research stability. I look forward to reviewing the budget and hearing from our NSF and public witnesses. Thank you.

Senator GORTON. Thank you, Senator Heflin. We will begin with Dr. Keyworth, and he is welcome here.

**STATEMENT OF DR. GEORGE A. KEYWORTH II, SCIENCE ADVISER
TO THE PRESIDENT**

Dr. KEYWORTH. Thank you, Mr. Chairman.

I have a comprehensive statement which I will ask to have inserted in the record.

Senator GORTON. Your entire written statement will be included in the record as if read.

Dr. KEYWORTH. Thank you.

At this time I would like to take just a few moments to cover three issues that I know the subcommittee is particularly interested in, after which I will be glad to answer questions on those and other topics.

Let me start with my prospectus on the proposed engineer centers, which address the kind of training we are providing for the bulk of engineering undergraduates, those who expect to enter industry. Today we are in the midst of a revolution in the way engineers work and the way modern industry operates.

That revolution is spurred by today's almost unbelievable leaps in science and technology—technology that is putting potent new computer tools in the hands of the product designer and that is blurring the distinctions between disciplines. Successful manufacturers are those who understand the entire process, from marketing to design to manufacturing and distribution. Increasingly, the computer and people who know how to use its full potential are the central elements in that process.

Unfortunately, very few of our universities are able to prepare their students to operate in that kind of environment. This is not their fault, but reflects a combination of lack of modern equipment and overburdened faculty who are struggling just to keep up with teaching demands.

But we see several hopeful signs that promise to help them overcome those limitations. In particular, industry and universities are working together to better define the kinds of working environments that new graduates will enter. In 1985 the National Science Foundation will initiate a new program in universities to integrate both research and teaching needs for engineering.

This program is being developed with the broad participation of the engineering community and the National Academy of Engineering. The aim is to establish cross-disciplinary centers in which students and faculty can work on broad research problems of the type facing industry, and use the modern tools and methods that industry uses. This is one of several efforts at NSF to improve engineering research and education, that I am sure that you and Dr. Knapp have been and will be discussing more.

Second, let me turn to the problem of research instrumentation. We recognize the important need within universities to improve and update the facilities available for research. We have adopted a policy of building support in large part for new instrumentation and equipment directly into the project grants.

That is a primary reason why NSF, for example, is using its increased funds to emphasize larger, rather than more, grants. Across all the R&D agencies, we expect to provide more than \$400 million in fiscal year 1985 for research instrumentation available for university scientists and engineers.

We recognize that this amount, while substantial, falls far short of the estimated needs for new instrumentation in the Nation's universities. After all, the problem arose over an extended period of underinvestment in university research instrumentation. And I must emphasize that even if it were possible, it would be foolish to think that this is a problem that could or should be solved all at once with some kind of one-shot program.

Keeping up with new technology must be a continuous process, and we intend to provide the substantial sums of money on an ongoing basis to address this problem. Our preference for including much of that support as part of actual research grants rather than as separate instrumentation programs is to emphasize that instrumentation is as much a part of modern research as any other expense, to permit new instrumentation to be tied closely to highest priority research programs, and to give researchers themselves as much discretion as possible in deciding how best to allocate research funds.

Finally, I want to say a few words about supercomputers. I believe we all agree that it is imperative for our academic research community, faculty and students, to have opportunities to work with state-of-the-art computing tools. Let me suggest three main reasons for this importance.

First, the direct benefit to frontier research. Supercomputers offer the best known way to attack many large-scale science and engineering problems, a way to model complex physical interactions.

Second, the opportunity for young scientists and engineers to learn what supercomputers can do and to become familiar with them. After all, these people are the ones who will be developing the supercomputers' potential for solving new kinds of problems in the future.

Third, the vital contributions that the research community will make to designing and developing the software to make the supercomputers even more useful in the research process.

In fiscal year 1985, the National Science Foundation and the Department of Energy plan to provide increased access for university researchers to supercomputers, both by allocating greater amounts of time on supercomputers at national laboratories and by installation of new supercomputing facilities dedicated to academic users. NSF will also be installing a class VII supercomputer at the National Center for Atmospheric Research for use by the atmospheric and ocean sciences community.

In parallel efforts, DOE, NSF, and DOD will fund increased research in various areas of computer science and electronics that will be applicable to future generations of supercomputers. We are confident that these varied activities, in conjunction with continued purchase of the most advanced supercomputers for direct Government use, will in turn provide the market incentives to permit

U.S. commercial manufacturers to maintain their technological leadership in this field.

Mr. Chairman, that concludes my summary. I would be pleased to answer any questions.

Senator GORTON. Thank you very much, Dr. Keyworth.

In your testimony you noted that the approach to instrumentation needs is to include the support as part of actual research grants. Would multiuser centers of equipment be a more efficient way of allocating scarce resources?

Dr. KEYWORTH. I would say it is one mechanism that very much should be emphasized. I am sure it is not the only means by which we can address the instrumentation needs. Really, we need to develop centers, in my opinion, to bring the needs and environment of industry closer to the training process and to permit cross-disciplinary research.

The time has come where a mechanical engineer is entering a period where he will need to work with a biotechnologist, something that is almost heretical in terms of the past way we pursued engineering. And we need centers to recognize that change.

Clearly, those centers must have the best and newest instrumentation if we are to, if you wish, ease the transition to industry. But the disciplinary basis in science departments and engineering departments must also be restored.

I would say, yes, that is a keen thrust, but not the only thrust required.

Senator GORTON. How many such centers are there in operation now?

Dr. KEYWORTH. Primary examples now are—materials research laboratories are the best examples I know of, that the National Science Foundation funded and that were originally started by ARPA in DOD. I do not remember the exact number, but there are approximately 10 and they are relatively small.

I do not think we are talking about encouraging something that is widely established as much as we are encouraging something that is perceived as a very exciting mechanism today by many universities and industries. So we do have a lot to do.

Senator GORTON. As I mentioned in my opening statement, we see reports of tests conducted by the Lawrence Livermore Labs that indicate that the Japanese may be on the verge, if they have not already accomplished the process, of overtaking the U.S. lead in supercomputers. Do you believe this to be the case?

Dr. KEYWORTH. I do not believe that that particular description of the problem is quite the same as my own perception, but not far away. Let me phrase exactly what I think the problem is.

We have never been challenged in our supercomputer capability, never, by any other nation. Today we are clearly challenged by the Japanese industry that is committed to entering the forefront in its initial efforts in supercomputers.

I do not believe that American industry perceives this as if defeat were on the immediate horizon or, even worse, as many of the newspapers have represented, is here. That is not the case. But clearly, they are truly being challenged, and clearly we need to think very carefully about the importance of supercomputers and how we can encourage their rapid development.

Remember that supercomputers have traditionally been in large measure a requirement of the U.S. Government more than of our industrial and private sector. So I believe that the Federal Government has a key role. I think we must look carefully at where industries are going. We must provide the encouragement, for example, by a concerted definition of Federal Government immediate and future requirements for defense and other activities. We must pay particular attention to training the kind of people who can utilize and exploit supercomputers, because one of our major advantages is in software development, an area where the Japanese lag considerably.

Senator GORTON. You really anticipate my next question, which is the implications of this challenge for our research, and the question as to whether the \$20 million asked in the NSF budget is adequate to meet it. Yesterday's Washington Post, for example, indicated that it was Dr. Kenneth Wilson's belief that we needed an allocation of \$100 million, in effect to buy forward, to pay in advance of production, to encourage more rapid development of such supercomputers.

Can you comment, both specifically on Dr. Wilson's proposal and more generally on whether or not NSF within the parameters of this budget can meet the need?

Dr. KEYWORTH. Yes; first, we have discussed ourselves extensively with Dr. Wilson his own perceptions of the need and opportunities. I would say the choice of \$100 million is largely selected because it is one of the round numbers, greater than \$10 million and less than \$1 billion.

But what we have attempted to do instead is to look very, very carefully at how a program could develop within the universities. I must remind you that we have in the past maintained efforts to stimulate the development of computers in universities, and they have not been universally successful.

Frequently a university has been overwhelmed with computing capability without having developed the disciplinary base to pursue it and use it effectively. With that in mind, the National Science Foundation, Dr. Knapp and I have spent a lot of time together pursuing this. We wish to build a strong program that will continue to grow, but it must respond to first class, well-thought-out university proposals, instead of just trying to stamp supercomputer centers on universities that will be overwhelmed by this almost revolutionary capability.

So I believe that the \$20 million is a well thought out, appropriate number. I also believe that that number, if I may deign to predict, next year that number will be substantially larger because I think there will be a lot more activity within universities and it will be evidenced in a host of strong, well-thought-out proposals.

Senator GORTON. Would you go on with the implications of that outline on the purchase of the NCAR computer and the NBS computer and whether you think there is any chance that we will be making purchases from Japan.

Dr. KEYWORTH. At the moment I think it is very unlikely that we will be making purchases from Japan, because the tests that have been performed so far are extremely preliminary. Let me say that from my own experience at one of the major computing centers in

the United States at Los Alamos, the evaluation of a supercomputer is not a trivial task.

A very small kernel program has been run on the Fujitsu machines in Japan, but it is only a very preliminary comparison, and the comparison between it and American products has not been done on what we call a dual processor U.S. computer.

At the moment I feel very confident in saying that the NBS and NCAR machine and others within the U.S. Government will be definitely inclined to buy one of the American products; 5 years from now, I am confident but by no means complacent that that will continue to be the case, and will be justification for many of the actions we are taking.

But let me just emphasize that the American manufacturers of supercomputers are not sitting back. They are vital industries, they are dynamic, they are extremely thoughtful. They have been in very close contact with us and other members of Government during the past 2 years. This is not a new issue. They are characteristic of the kind of competitiveness in industries today that I think is inspiring a new national optimism.

Senator GORTON. Some members of the science community have called for a national computer network to link all of the science and engineering disciplines. Do you see the need for such a network, and if so do you have any plans for one?

Dr. KEYWORTH. A massive network to meet all networks I think is just oversimplified and will not work. On the other hand, Dr. Knapp and I have discussed extensively the fact that some universities will be able to develop a clear disciplinary base to utilize an entire supercomputer by itself.

Others may want to develop either a regional system or a disciplinary system; a disciplinary system, for example, that would meet the needs of materials scientists or, as we already have, fusion scientists, across the entire Nation. We will very definitely be using both options, and I think we will continue to see a lot more networks developing.

But the technology moves much too rapidly to think that we can simply meet national computing needs by installing a host of very, very large centers. Where we will be in 5 years and whether supercomputers will even be an appropriate computational tool for most university researchers I think is beyond anyone's imagination, even though 5 years is not very long.

Senator GORTON. Thank you.

Senator Heflin.

Senator HEFLIN. Dr. Keyworth, we welcome you to this committee. We always enjoy having you here and learning your visions of the future and your thoughts.

Pursuing a little bit what Senator Gorton has explored with you about the supercomputer, you testified that the Lawrence Livermore National Laboratories comparisons of cost effectiveness are preliminary. I know that the National Bureau of Standards wants to buy a supercomputer, the National Center for Atmospheric Research is seriously considering means by which to acquire a supercomputer, and the Lawrence Livermore Laboratories indicate that, even if it is preliminary, maybe Japanese computers are 2 to 3 times more cost effective than the U.S.-built machines.

Now, you indicated these are preliminary estimates, but it is rather startling to know that even in a preliminary stage they can be so much more cost effective. This raises a question. It raises a question, along with other evidence, as to whether we are lagging behind the Japanese considerably in the supercomputer field, and whether in another year in the future we will lag even further.

Obviously, there is a coordinated effort by the Japanese, with the Government, the private sector, the research universities, and others to coordinate work relative to these matters. I just wonder whether or not it would be advisable for America to bring together people from all of the various disciplines and all of the segments involved in industry, Government, and others, maybe in effect to form a task force to be a think tank to develop a blueprint of the future development of the supercomputer, similar to the rather successful experimentation in the Spacelab on building crystals. I wonder whether or not some sort of task force, institute, or some sort of think tank would be appropriate to consider a short-range or long-range role for Government in the development of the supercomputer.

We are very much proud of the fact that industry has done it in the private sector. Computers have not been in effect Government financed. But it seems to me that preliminarily evidence is indicating that the Japanese are getting ahead of us.

You admit that there is a substantial threat. We can lose our leadership in this area. I know we have lost it in other areas. It seems to me that now would be the time for some proper planning, the proper creation of an appropriate, well rounded, constituted think tank to develop sort of a blueprint for the future.

What is your feeling relative to this?

Dr. KEYWORTH. Mr. Heflin, I share many of your concerns, and I have asked myself many of the same questions. I very much appreciate your interest on this very important subject.

Let me share with you a few of my own observations during this period of time. And again, I want to be cautious about one particular thing. I am concerned. I am not complacent. I am confident. That is very different. Being confident here is very different than being complacent.

We are clearly challenged. The Government needs to take a very realistic role, if for no other reason than simply because so many Government responsibilities depend so critically upon our numerical simulation capability with supercomputers.

So the Government does have a role. The Government needs to be closer to the assessment of our present and future capabilities than I think we have been in the past. But as far as whether the Japanese are better than us, let me point something out. We treat today as the primary supercomputer in the United States a Cray I. That is the computer, for example, that is a candidate for the machine which NBS will be purchasing, and that is the standard against which the Fujitsu DP-200 machine has initially been compared.

I first used an earlier version of the Cray I in 1976. That is almost 8 years ago, and in that period of time we have seen concepts such as the RAM emerge into the stage of very high development and very rapid evolution.

I have been following this for at least 2 years, when the House Armed Services Committee first expressed some concern to some of us in the White House. In other words, I do not believe the Japanese are way ahead of us, but I think we are going to have to move very quickly to be confident that they will not be in 5 years.

We do have an initial coordinating and overview operation within the U.S. Government, something in the executive branch, something we established 1 year ago. We have a coordinating committee that has brought all of the interested agencies together, both to analyze and to develop their programs in a compatible, mutually reinforcing fashion.

The real threat that we are focusing upon, Mr. Heflin, is something that may sound somewhat specific here, but I quote a truly great American genius. A couple of years ago he said that he is perfectly capable of designing a computer today with 16 or 64 parallel processors, if you wish, simultaneous brains. But the trouble is, he built one with too many years ago and we still have not learned how to use it properly.

We have not paid attention to training and discipline of young people who know how to use what I am referring to here as parallel processing, and that is one of the major thrusts of the DOE and NSF program this year. We can keep American industry responding and way out front if our youth can be dynamic.

As an analogy: The United States, of course, began the automation industry, if you wish, robots, and it is the lack of vitality of American industry in applying the use of robots that has strangled the American robot industry. By the same token, we can strangle the American supercomputer industry by not being dynamic and visionary in using this emerging new technology, and that is where we believe that applying a lever will offer the greatest return.

Mind you, I think that is where the major very large computing industries feel that the greatest stimulus will come from in the United States also.

Senator HEFLIN. The agency you said you created a year ago, as I gather, is a Government agency coordination entity?

Dr. KEYWORTH. Correct.

Senator HEFLIN. It seems to me that we are at a stage where we need to bring the best minds from industry and Government and the academic community together into some formalized setting, with tasks to evaluate the program. Maybe you are correct on Livermore's evaluations. But it certainly looks to me that we are in a stage where enough questions are being raised that a red flag or a caution flag is going up, and if we are going to look to the future we ought to be in effect having some sort of planned approach to be sure that we do not lose the leadership in this area.

Dr. KEYWORTH. Mr. Heflin, I agree with the sentiment that we must be aware of where the technology is going in our country and where it is going in Japan. The thing that I dread, however, is the thought of the Government bringing together a group of visionary scientists to chart the technology path that industry should pursue.

I think that is a clear path to disaster. I think those industries are ideally positioned to respond to demand in a very aggressive fashion. I believe if we look at the most rapidly evolving area of American industry, and specifically I refer to the microelectronics

industry, I think we see that the flexibility that is built into our free system is what is keeping them the most dynamic, probably the most dynamic part of American industry.

So I would agree on the one hand that agencies like the National Science Foundation and the Department of Energy should make certain that the minds in universities and our Federal research centers are assembled so that we can spend these Federal dollars in a most effective fashion, and I believe they do, and will continue to need that capability.

But the specter of a group of academic scientists and Federal laboratory scientists literally charting out the architecture and technology for the next generation or the generation after of supercomputers I think is a potential disaster.

Senator HEFLIN. I do not believe that this task force is going to have all of that power. I would assume it is a matter of bringing together minds for discussions. I am sure there will be dissents, just like any other commission that has ever studied anything. There are all sorts of groups. I never have seen where the recommendation of a task force or anything else was mandatory on them as to what they were going to do.

I have the fear it would be a disaster if they would chart something and everybody would have to follow it. But I do not think America is necessarily going to follow any such recommendation. And certainly, as with changing technologies, it may well be that 10 years from now new thoughts and new ideas not even in anyone's human mind now may emerge.

I really do not see why you are worried that it would have a restraining effect.

Dr. KEYWORTH. My fear is that if we established a committee to devise, a task force to devise optimum technology development paths, that would be very likely followed up by Government support of technology development, and we would find ourselves on a path, if you wish, a commitment, that would be very difficult to change.

Let me offer an example. Recently, just 2 or 3 years ago, it was perceived within the microelectronics industry in America that the near-term future lay down two possible opportunities. Either Josephson junction technology or gallium arsenide technology. During that period of time, we have come to realize that we have many generations yet available in silicon technology.

The industry has flexed very, very rapidly. I would contend, perhaps, with some of the experience that we saw with the Department of Energy in the seventies, I would contend that with the Federal Government supporting and playing a heavy role in the development of microelectronics, the Federal Government would be happily going along on some blind dead-ended path, while industry can respond in a matter of weeks.

I think the supercomputer industry is exactly one of those rapidly responding areas. But Mr. Heflin, I certainly feel it is important that we in the executive branch and you in the legislative branch have up to date, well-thought-out information that will permit you and us to assess the magnitude of that challenge. And I am certainly not coming before you today saying that you have had that opportunity in the past.

I believe that we should assemble people to look at the state-of-the-art in the United States and to look at the opportunities before us. In that sense, I take your suggestion to heart, and I only express to you my own fear of going too far in this direction.

Senator HEFLIN. It was not my intention to say that that task force would ever go to the extent of making something mandatory. It would just try to develop ideas and see whether there is a role. It may well be that it acts as a catalyst for more industry participation.

Let me ask you this. Would you comment on the success of the Spacelab experiments relative to the production of crystals at zero gravity. Did it come out better than was expected in your opinion? Would you give us some of your evaluation of the success of that aspect of the Spacelab experiments?

Dr. KEYWORTH. Certainly. I will give you the best speculations that I have. I am sure you realize the full assessment of the scientific experiments on Spacelab I are by no means completed yet, and I think what will be most important is to see, for example, in Science magazine, a special issue that will come out I believe in May, a complete description of all the experiments, and then we will see where they fit into the state of American materials science.

But as a preliminary speculation, let me say this. I think that the experiments were essentially successful, as expected. We learned a lot about new capabilities, new techniques. I do not think by any means that we have demonstrated a new industry, nor a significant impact on the materials industry in America to date.

In particular, let me offer an example. We have for some years talked about opportunities of manufacturing very high grade gallium arsenide, which is a very important potential ingredient for high speed circuits. I made the effort some months ago to look across the broad spectrum of American industry for the real leaders in this area nationally, and found that most of them in their proprietary research programs were making extremely rapid progress in the processing of gallium arsenide and felt that they were going to meet their manufacturing needs in a very rapid time scale.

In that sense, I am not sure that many of the speculations of the past that the zero gravity or microgravity environment would give us a major new capability in electronics materials. We have a lot to learn in the future and I am optimistic. But so far I do not see any startling impact.

In the biological arena we have even greater unknowns, and I look at this with particular interest. But I do not think we want to—I would caution at the moment against overreacting to any of the materials experiments demonstrated so far.

What we have seen is technology. We have learned something about know-how and what we can expect to do in space. But it is a great big open area for us. I think we will be looking with enthusiasm and interest over future years. But again, I caution against overreaction at this point.

Senator HEFLIN. In previous appearances when you have been here, I have asked you about developments in laser R&D coordination and the technology development and application of lasers within the Government. Would you care to comment about the

present state of laser technology coordination in the Government and what the future might hold?

Dr. KEYWORTH. Mr. Heflin, I could not believe we could finish this hearing without bringing this up, and I was waiting with enthusiasm.

Yes; I would like to comment, and I would even perhaps like to share a little frustration. I personally believe that the speech that President Reagan gave 11 months ago is a speech that we will look back upon in the future as a milestone in the development of U.S. defenses.

I feel also it has been a lesson to me in observing how the bureaucratic system responds to top-down leadership. I believe this was an example of the kind of leadership that true leaders exercise and that we have not seen for a long time. I believe that much of the response from, if you wish, the Government system was symbolic of what many of us have become so concerned about in the bureaucracy's ability to react to change.

I do not believe that we have the kind of coordinated program at the moment that addresses the President's objectives in that speech. I do believe that we are making headway. I also confess that I think it is painfully slow headway.

Mr. Heflin, I expressed to you nearly 3 years ago some concern about the fact that we were not quite at the point of development of laser technology to achieve the kind of goals that many of us believe are eventually capable in ballistic missile defense. I do believe that, as a physicist, those technologies are here today. I say as a physicist because we have not demonstrated the kind of large systems that we need, but there is no more physics that we have to learn. If we are not pushing the frontiers of science, we need to do a lot of clever engineering.

I could not say that 3 years ago, but I feel extremely optimistic today. I believe we should rapidly pull together a tightly coordinated, if you wish, redtape-free program that uses the very strong capabilities of American industry and American technology base to gain a strong capability in this area.

I believe—and I share this sentiment totally with Secretary Weinberger, and I feel that we have very similar opinions on this issue—it is essential that we proceed early in this fiscal year to develop a very strongly coordinated program to direct fiscal year 1985 programs in ballistic missile defense development. I believe that getting a streamlined, well-run and operated program is essential, and I applaud your observations and concerns of several years ago.

I can only say that many of us are committed at this time to supporting the President's call last March and in trying to develop a strong and much better program than we have today.

Senator HEFLIN. Well, does the development of the technology, the physics of laser technology, mean that there are also other governmental, nonmilitary uses that have been undertaken in the past that now might be accomplished? I would refer to matters like the possibility of laser-induced nuclear fusion.

Are there areas which are nonmilitary that the Government has been involved in with experiments and that business has been involved in with experiments, that the advancement in the physics of

laser technology will mean that it has more realistic applications for the future?

Dr. KEYWORTH. I believe any major technology development program will have benefits and spinoffs in other areas. But let me point out—let me say something quite positive here. The development of laser technology in the last 10 years in the United States in the private sector and in the research laboratories, nondefense-related, has been extremely good and extremely dynamic.

Our ability to produce lasers across, let us say, across the color spectrum, tunable lasers, has been momentous and bodes extremely favorably on the field of photochemistry, using lasers to alter chemical processes and catalyze them. We of course are using, as I am sure you know, lasers to do things like treat surfaces of metals and other very practical applications.

It is moving very rapidly there. The problem is—and the problem is true in so many other areas of defense—that the very dynamism that is out there in industry and in our pure research environments is only slowly bled into the defense arena. I do not think the dynamism—whereas there are some exciting programs in DARPA and other parts of the Department of Defense in laser technology in general, I do not think that their programs reflect the same kind of dynamism that is being seen across the spectrum of laser development elsewhere.

So it is not that a push here in the defense arena is going to revolutionize what is happening in the private sector. But what I really am saying is that a major strategic need, a major need for future strategic stability, can be heavily met by simply taking the benefits that are available out there from what is happening in American science and American industry.

Senator HEFLIN. Thank you.

Senator GORTON. Thank you very much, Dr. Keyworth. We are pleased, as we always are, to have you here to help us in this respect.

Dr. KEYWORTH. Thank you very much.

[The statement follows:]

STATEMENT OF DR. G. A. KEYWORTH II, SCIENCE ADVISER TO THE PRESIDENT AND DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

Chairman Gorton and members of the subcommittee, I look forward to this opportunity to meet with you to discuss the Administration's overall science policy and its relation to the programs proposed for fiscal year 1985 for the National Science Foundation. I hope my presentation and our discussion today will make two things clear. One is our consistency in applying those basic principles of science policy that were enunciated at the start of the Administration. The other is our continuing success—the Administration's and the Congress's—in strengthening American science and technology to respond to the rapidly changing world in which we live.

By their nature, science and technology demand long-term planning and preparation, starting early in the educational process and extending into the maturing of young researchers and their integration into the research academic, or industrial communities. Major facilities may take a decade to develop and may be used for decades more. It's clear that the planning cycles for the world of science and technology are far longer than the turnaround times in the political arena. So those of us who accept the responsibility for charting the course for government programs in science and technology must also accept the responsibility for clearly articulating—and sticking to—basic principles for guidance.

In discussing the Administration's science policy and the proposed fiscal year 1985 R&D budget today, I propose to focus on those same three principles that have un-

derlain our programs all along. Our three goals for science policy are these: First, the development of the highest quality technical talent we can produce; second, the continuing pursuit of excellence in whatever research we choose to do; and third, the expansion and strengthening of partnerships between government, industry, and universities for the purpose of bringing the benefits of new knowledge and advanced technology to our nation.

Those of you who have heard me on the subject of R&D policy know how strongly we've stressed the importance of the federal government's role in support of basic research. I've even referred to that responsibility as a federal trust. Not only is basic research an essential investment in the nation's long-term welfare, but it's largely a federal responsibility because its benefits are so broadly distributed. Quite simply, basic research is a vital underpinning for our national well-being. There are three reasons for that.

First, research grants to universities, where the majority of the basic research is done, permit the training of tens of thousands of graduate students under some of the most demanding and stimulating research conditions anywhere. This new talent will be responsible for maintaining American technological leadership in coming years.

Second, strong support for basic research permits U.S. scientists and engineers to challenge intellectual frontiers in the most important fields of science and technology. That provides the new knowledge that drives our economic growth, improves our quality of life, and underlies our national defense.

And third, well chosen basic research projects stimulate productive partnerships between scientists and engineers in all sectors of society—partnerships that are increasingly vital to development of new technologies that will keep American industry competitive with improving foreign companies and will speed the application of new knowledge to our increasingly technological defense needs.

This year's budget is the fourth one that the Reagan Administration has prepared from scratch and sent to Congress. We're presenting a strong program of research and development for the coming year, one that continues to strengthen the nation's capacity to conduct R&D and train new scientists and engineers, and one that permits important new projects to start. But before discussing how our fiscal year 1985 programs meet those objectives, I want to take a few minutes to assess the cumulative impact of R&D policy during the Reagan Administration's first four years.

With your permission, I'd like to refer to the three charts that are attached as the last pages of my prepared text. All these charts refer to non-defense R&D, which is the area of the budget that I want to concentrate on today.

The first chart I'll refer to is titled "Federal R&D Obligations." Over these four years the Administration's science policy has been committed to an emphasis on basic research, for the reasons I've just described, and a concomitant reduction of government support for demonstration, development, and applied research projects that are more appropriate for the private sector. In particular, we made substantial reductions in energy-related demonstration projects. This is a reflection of both common sense and economic reality. So when we look at the three categories of federal funding in non-defense areas—basic research, applied research, and development—we see a startling shift in relative priorities during this Administration. Please note that this and the other charts show constant 1983 dollars, which means the curves have been corrected for inflation and represent actual purchasing power. You can see how basic research has gone from the smallest fraction of that non-defense R&D to the largest, with a jump in share from 27 to 38 percent—more than a 40-percent increase. At the same time, development funding has dropped by nearly 50 percent.

To see more specifically how that federal support for basic research has grown, we turn to the chart titled "Basic Research Obligations." It shows basic research for the five largest R&D funding agencies since 1978—again, in constant dollars. As you can see, all five agencies have had strong and consistent growth, and in four of those cases that growth follows level or even declining real budgets in the five years before.

Finally, on the chart titled "Basic Research Obligations to Universities and Colleges" we can see the growth in basic research funds that have gone specifically to universities and colleges. Here the result of the science policy is even more pronounced. Although it's not shown, we could trace a consistent decline in basic research funding for universities back to 1968, and where the chart picks up we see that there was essentially no growth from 1979 to 1981. However, from 1981 to the level being proposed for 1985, this support for universities grows by 26 percent—again, in real terms.

Moreover, the true impacts of federal funding on universities are even greater, because so much university research draws on federal investment in unique centralized facilities. Substantial amounts of the funding that goes to federal and national labs actually support university research in physics, astronomy, materials sciences, and space sciences. So I want to stress that these graphs and numbers reflect a point I've been making for as long as I've been in Washington—that during this period we've been seeing the strongest support for basic research in twenty years.

I want to call your particular attention to the consistency shown in these trends, because, as I mentioned earlier, one of the most serious detriments to good science is what is called roller-coaster funding. Most good research programs require many years to plan and carry out, just as it requires many years for new ideas and, especially, new talent to develop, mature, and become productive. So I see this consistency as a major element of science policy, an element that I hope the Administration, the Congress, the science community, and the public will be able to maintain in coming years.

Now, with that as prelude, let me briefly discuss some of the highlights of the President's proposed fiscal year 1985 R&D budget.

Total federal R&D will increase in 1985 to \$53 billion. Over the four years of the Reagan Administration federal funds for R&D have increased by 52 percent, with this year's increase being 14 percent. The largest increase in 1985 will go for defense R&D, which increases 22 percent and will support continuing defense modernization. We're still in the position of having to pay special attention to these defense modernization needs to compensate for inadequate funding during the previous decade.

Basic research is targeted for the next-largest increase, 10 percent, and will rise to \$7.9 billion in 1985. Basic research at NSF, however, will grow by somewhat more—13 percent. Since 1981 federal support across all agencies for basic research has increased by 55 percent, a growth of nearly \$3 billion. Half of that support goes directly to universities and, as I said, a good bit more is destined to make possible faculty research in federal facilities.

As in previous years, you'll find we're applying those basic research increases selectively to areas of strong opportunity and excitement. Although not readily identified in the budget information, we continue to give high priority to project support for university research through agencies like NSF, NIH, DOE, DOD and NASA. This kind of support is the most important element of the budget in continuing on the path to restoring the health and vitality of our nation's universities.

I would also point out that we recognize that important need within universities to improve and update the facilities available for research. We've adopted a policy of building support in large part for new instrumentation and equipment directly into the project grants. That's a primary reason why NSF, for example, is using its increased funds to emphasize larger, not more grants. Across all R&D agencies, we expect to provide more than \$400 million in fiscal year 1985 for research instrumentation available for university scientists and engineers.

We recognize that this amount, while substantial, falls far short of the estimated needs for new instrumentation in the nation's universities. After all, the problem arose over an extended period of underinvestment in university research instrumentation. And I must emphasize that even if it were possible, it would be foolish to think this is a problem that could, or should, be solved all at once with some kind of one-shot program. Keeping up with new technology must be a continuous process, and we intend to provide these substantial sums of money on a on-going basis to address this problem. Our preference for including much of that support as part of actual research grants rather than as separate instrumentation programs is to emphasize that instrumentation is as much a part of modern research as any other expense, to permit new instrumentation to be tied closely to highest-priority research programs, and to give researchers themselves as much discretion as possible in deciding how best to allocate research funds.

I said earlier that there are three broad goals embodied in our programs for science and technology. These relate to assuring the continuing supply of bright new technical talent to meet national needs, to selecting the most important and most relevant fields of R&D to pursue and then pursuing them as well as we possibly can, and to stimulating new and productive partnerships that span the range of people and organizations conducting R&D.

To help explain the kinds of specific activities that we're proposing to achieve those goals, I want to describe just a few of the fiscal year 1985 initiatives in those contexts. Each of these examples embodies our determination to retain U.S. scientific and technical leadership in those fields we believe to be most important.

Without hesitation I would assign highest priority to stimulating and nurturing technical talent. Over the past several years I've had interactions with hundreds of our Nation's industrial and university leaders. Almost to a person they echo that priority. Now, especially as the economy has resumed strong growth, industries that depend on technical talent are feeling the pinch. In many of the fast-growing fields—the ones that create new jobs and products for export—there simply aren't enough really good people to go around. We face problems of both numbers and quality. We face problems that threaten to put a brake on the ability of our economy to continue to grow.

As you know, one of the really exciting programs approved for fiscal year 1984 was the National Science Foundation's Presidential Young Investigator Awards. I'm pleased to announce that the first 200 of these awards were announced last week, and NSF is already gearing up for the second round of 200 to be made in fiscal year 1985. My understanding, from discussions with industry, is that the universities involved are likely to be very successful in lining up industrial support to match the federal funds. We expect virtually all the awardees to realize the full \$100,000 per year research support possible.

Part of the motivation for this program is to attract and retain top-quality young faculty in universities, especially in those fields where faculty shortages are severely limiting our ability to meet the growing demands by students for training. But, over the past year, in conversations with the academic and industrial engineering community, we've become increasingly concerned about another problem—the kind of training we're providing for the bulk of the undergraduates—those who expect to enter industry.

We're in the midst of a revolution in the way engineers work and the way modern industry operates. That revolution is spurred by today's almost unbelievable leaps in science and technology—technology that's putting potent new computer tools in the hands of the product designer and that's blurring the distinctions between disciplines. Successful manufacturers are those who understand the entire process, from marketing to design to manufacturing to distribution—and, increasingly, the computer and people who know how to use its full potential are the central elements in the process.

But very few of our universities are able to prepare their students to operate in that kind of environment. This isn't their fault, but reflects a combination of lack of modern equipment and overburdened faculty who are struggling just to keep up with teaching demands. But we see several hopeful signs the promise to help them overcome those limitations.

In particular, industry and universities are working together to better define the kinds of working environments that new graduates will enter, and industry is offering virtually no-strings-attached help to many schools in the form of direct funding for new programs and modern equipment for student use. Certainly what I've seen in the past year suggests the dawning of a new age of enlightenment for engineering education.

Clearly the federal government has a key role in this transformation. In light of the kind of competitive environment that U.S. industry is going to continue to operate in for the rest of this century, we want to help our universities provide the best kind of training possible.

So in 1985 NSF will initiate a new program in universities to integrate both research and teaching needs for engineering. This program is being developed with the broad participation of the engineering community and the National Academy of Engineering. The aim is to establish cross-disciplinary centers in which students and faculty can work on broad research problems of the type facing industry—and use the modern tools and methods that industry uses. This is one of several new efforts at NSF to improve engineering research and education at universities—efforts that I'm sure you and Dr. Knapp are discussing.

Now let me describe a completely different kind of program that, in an important way, also relates to this concern for talent. I'm referring here to the development, acquisition, and availability for the research community of supercomputers. I believe we all agree that it's imperative for our academic research community—faculty and students—to have opportunities to work with state-of-the-art computing tools.

Let me suggest three main reasons for this importance. One is the direct benefit to frontier research; supercomputers offer the best known way to attack many large-scale science and engineering problems, a way to model complex physical interactions. Second is the opportunity for young scientists and engineers to learn what supercomputers can do and to become familiar with them. After all, these people are the ones who will be developing the supercomputers' potential for solving

new kinds of problems in the future. And third is the vital contributions that the research community will make to designing and developing the software to make the supercomputers even more useful in the research process.

Mr. Chairman, I want to briefly outline some specific efforts being proposed for fiscal year 1985.

Both NSF and DOE plan to provide increased access for university researchers to supercomputers, both by allocating greater amounts of time on supercomputers at national laboratories, such as through DOE's Magnetic Fusion Energy computing network, and by installation of new supercomputing facilities dedicated to academic users. NSF will also be installing a Class VII supercomputer at the National Center for Atmospheric Research for use by the atmospheric and ocean sciences community.

In parallel efforts, DOE, NSF, and DOD will fund increased research in various areas of computer science and electronics that will be applicable to future generations of supercomputers. We're confident that these varied activities, in conjunction with continued purchase of the most advanced supercomputers for direct government use, will, in turn, provide the market incentives to permit U.S. commercial manufacturers to maintain their technological leadership in this field.

I already described the importance of project support to the vitality of universities, but I should add that project support is also a primary means by which we reach the second goal—the pursuit of excellence. I would only add that the tried-and-true method of investigator-initiated, peer-reviewed research grants has produced phenomenal results over the years. The fact that U.S. scientists won four out of four Nobel Prizes in science last year reflects on the effectiveness of this kind of system for supporting basic research.

Although there are many, I'll offer only one specific example of a 1985 initiative intended to help American scientists continue to pursue excellence. And I offer it because it represents a field of science in which this country has been a world leader and also a field that demands extremely careful—not to mention wise—decisions about future programs.

In a sense, high-energy, or particle physics, is a field of science that pushes hardest at the frontiers of knowledge. The questions it asks are in many ways the most fundamental in nature, and the answers are surely among the hardest to find. Over the years there have been important direct applications to other areas of science and technology of knowledge first derived from this kind of front-line physics research.

But what I think we have to realize is that fields like this are important as much for the way they attract and stimulate human intellect as for their specific results. In a sense, fields like particle physics, or astrophysics, or molecular biology, or mathematics are stimuli for our broad national strength in science and technology.

Of those fields particle physics is no doubt the most expensive to pursue today. It's that expense that forces us to make, as I said, wise decisions about what course we'll pursue. It was that expense that led to a fundamental rethinking by the high-energy physics community, last year, of where the U.S. should be going in particle physics. The result of that introspection was the decision to terminate a major accelerator project that was no longer timely and focus attention instead on a bold step into new energy regimes with an entirely new accelerator looking at truly forefront questions in the structure of matter.

I believe such a project has strong merit if it can be designed and if it can be built for a reasonable cost, in a reasonable time frame. Those are big "ifs," and I don't think anyone can yet tell us if we can meet those requirements, but we're proposing that in fiscal year 1985 we begin the process of trying to find out. To that end the Department of Energy will begin R&D on advanced superconducting particle accelerator concepts. This would permit us, at some point later in this decade, to decide whether or not to proceed with the next-generation machine, a Superconducting Supercollider. Questions of how, where, how much, and, perhaps, with whom, are all deferred until we have a better handle on the technology. I emphasize that we propose no commitment to proceeding beyond this R&D; construction, should it appear feasible, will have to be decided later.

The third goal I mentioned, stimulating partnerships among scientists and engineers in universities, federal labs, and industry, reflects the pressing need to improve the transfer and application of new knowledge to national needs, particularly in industry. I think we've seen some real progress in the past few years in improving these interactions, not so much because of anything government has done as much as because of the broad national awareness of the need to respond to the obvious industrial and military competition from abroad.

My first example of better partnerships focuses on the field of agriculture. There's little question but that we have made only slow progress in bringing the benefits of the modern biotechnology revolution to American agriculture.

The result, I'm afraid, is that we've failed to take the prudent steps necessary to protect the enormous world leadership we've enjoyed for so long in agriculture.

We've already seen—painfully—how aggressive competitors who adopt new technologies and run with them can make severe inroads on what American industry assumed was a guaranteed market. Automobiles and consumer electronics come most readily to mind. I would hate to have to add agriculture to that list twenty years from now. Let me add that I don't expect to. We have tremendous resources in this country that should enable us to maintain and extend our world lead—but we have to start now to incorporate the fruits of molecular biology and its offshoots into a new field of agricultural biotechnology. To accelerate that process, in fiscal year 1985 the Department of Agriculture will greatly expand its competitive grants program. This will include a substantial new agricultural biotechnology research effort within that program.

I'd also like to bring the Committee up to date on another attempt to stimulate new partnerships—the Center for Advanced Materials at Lawrence Berkeley Laboratory that is now underway. The project has benefitted during the past year from thoughtful review and recommendations from the materials science community, recommendations that are being implemented. Our original objectives for the center are unchanged—a place to bring together a range of materials and other scientists from academia, industry, and federal laboratories to work on problems of fundamental importance to future technology.

Mr. Chairman, I can't think of any effort undertaken by my office that is more pertinent to this goal of promoting partnerships than our effort to improve the operations of the nation's more than 700 federal laboratories. I'd like to bring you up to date on the progress being made on implementing the recommendations of the White House Science Council's Review of Federal Laboratories. As you know, this review was done under the leadership of David Packard and resulted in a series of recommendations that were presented to the President last July. Following that presentation, the President instructed OSTP and OMB to lead an interagency effort to work on ways to implement the recommendations in the panel's report—and he directed the heads of federal departments and agencies to work with us in doing that.

The Packard Panel, after more than a year of study of the federal labs, concluded that the nation could be deriving far more benefit from these valuable R&D resources, and they recommended changes in five major areas to help improve their effectiveness. Without going into detail, I would just indicate that the recommendations called for clearer missions for the labs, for changes in the personnel systems to attract and retain top technical talent, for more stable funding and more autonomy for the labs themselves in managing their research, and for broader interactions between the labs and other public and private sector R&D organizations.

Over the past half year an interagency committee has been making good progress in developing approaches to carry out the recommendations. They've done this by working with lab and agency officials, with potential users of lab results, and with the original White House Science Council panel. And in this regard I want to specifically acknowledge the tremendous contribution that David Packard has made and continues to make in this effort.

Some of the recommendations, such as those encouraging greater interaction with industry and universities, can be implemented directly by the actions of the labs and parent agencies; other recommendations, such as those calling for changes in federal personnel regulations, will require legislation. As specific proposals begin to take shape, the individual agencies, as well as my office, will discuss them with the Congressional bodies that have oversight responsibilities in these areas. We hope that the bulk of this work will be completed by the time we report back to the President—July 1, 1984—through we all recognize that optimizing the return on our massive investment in federal labs—about one-third of the total R&D budget—demands continual attention to the nation's R&D climate and demands readiness to change as the times change.

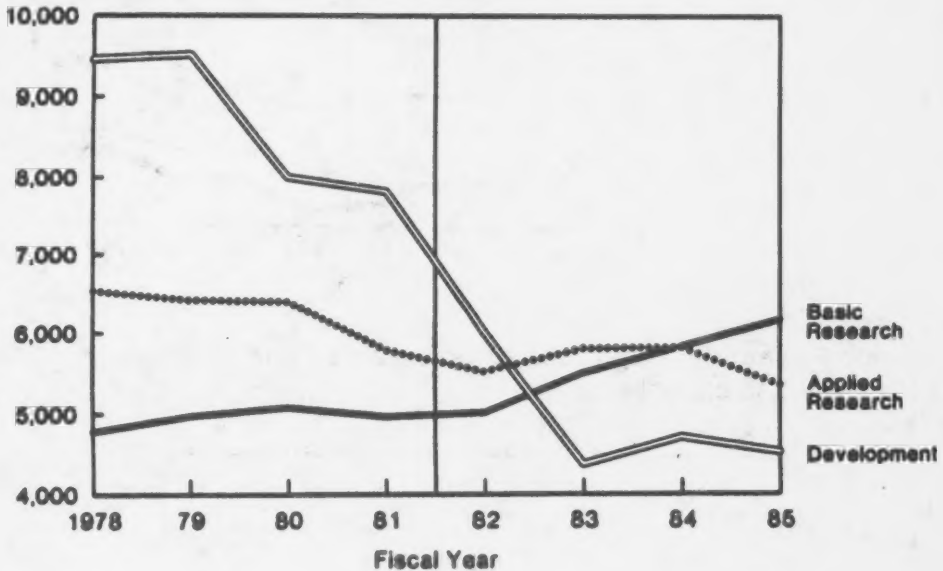
Mr. Chairman, I chose these few examples of fiscal year 1985 initiatives to give a flavor for how science policy is implemented. I could as easily have chosen many other examples, because the proposed program for fiscal year 1985 is indeed exciting. We have new space science missions, such as the Upper Atmosphere Research Satellite and the Mars Climatology/Geoscience Orbiter, in addition to the Space Station proposed by the President last week. We have an exciting proposal for a continuous electron beam accelerator facility to focus on the role of quarks in atomic

nuclei, an imaginative project under the direction of a southeastern university-based consortium. NSF will begin construction of a long-awaited and unique astrophysical facility, the Very Long Baseline Array of Radio Telescopes. NSF will also begin work on defining a possible continental drilling program to investigate important phenomena deep in the Earth's crust. And there are many more that you'll be hearing about as the individual agencies appear before the Congress.

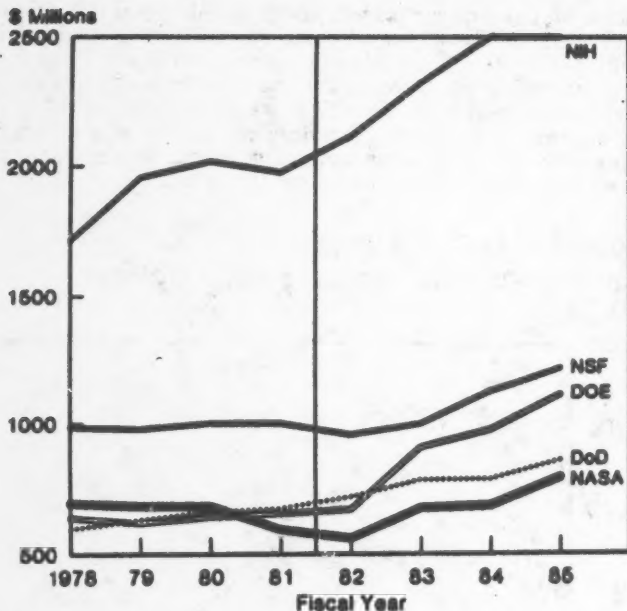
Mr. Chairman, this concludes my formal presentation. I would be happy to respond to questions from the Committee.

Federal R&D Obligations (Non-Defense) in Constant 1983 Dollars

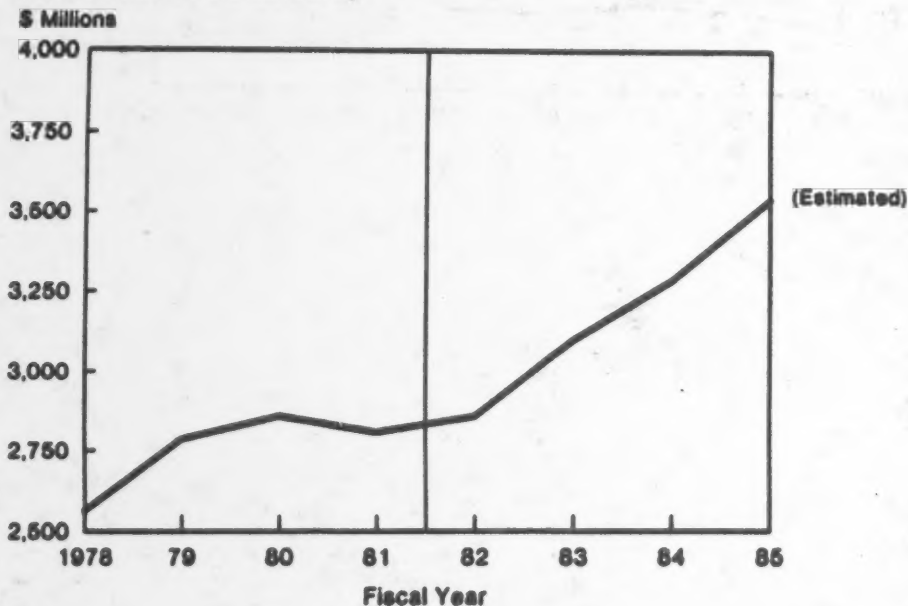
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**Basic Research Obligations
(Constant 1983
Dollars)**



**Basic Research Obligations to Universities and Colleges
(Constant 1983 Dollars)**



Senator GORTON. We will now proceed to a panel consisting of Dr. Knapp, Dr. Lane, and Dr. Zdanis. Dr. Knapp, welcome back for the second time in 24 hours. We are happy to have you with us again. And, as was the case yesterday, your entire statement will

be included in the record as if read. You may highlight it or deal with it as you wish.

STATEMENTS OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION; DR. NEAL LANE, CHAIRMAN, PHYSICS DEPARTMENT, RICE UNIVERSITY; AND DR. RICHARD A. ZDANIS, CHAIRMAN, VICE PROVOST, THE JOHNS HOPKINS UNIVERSITY

Dr. KNAPP. Thank you.

I am very pleased to be back again. I do have a statement for the record. I will summarize that to begin the hearings. I am pleased to be back for the second day of hearings on the administration's budget request for the National Science Foundation.

Mr. Chairman, investigators in almost every field of science and engineering depend more and more on research instrumentation and computers to conduct leading edge research. The quality and availability of these sophisticated tools have a major impact on the productivity and efficiency with which researchers work.

Research instrumentation is an extension of a scientist's senses when he or she asks questions of nature. Instruments are the eyes, ears, and fingertips through which a researcher experiences nature and discovers information.

Modern computers are powerful tools which enable the scientist and engineer to manipulate and interpret unimaginable amounts of complex data. This makes it possible for them to construct and manipulate models which simulate the behavior of phenomena in fields as diverse as economics and atmospheric science.

The Foundation's budget request for 1985 places a high priority on strengthening the research instrumentation base in our Nation's universities and colleges. These institutions conduct most of our fundamental scientific and engineering work and train our future engineers and scientists. Our request also includes a significant expansion of support of computer networking and research time on so-called supercomputers.

Let me begin my discussion of our 1985 budget proposals with two brief examples of improvements in instrumentation. Since all natural phenomena are related, the results of research in one field, say physics, often affect other disciplines in unexpected and revolutionary ways. Such interactions often result from the development of an instrument.

A prime example of this is the phenomenon of nuclear magnetic resonance, investigated by the physicists Bloch at Stanford and Purcell at Harvard, both of whom received the Nobel Prize for their work. Bloch and Purcell were working independently on an esoteric problem, the behavior of substances in a magnetic field when they are irradiated by radio waves.

Soon the phenomenon of nuclear magnetic resonance, originally studied for its own sake, was developed into a nuclear magnetic resonance spectrometer, a tool for probing the nature of molecules themselves. Without exaggeration, the application of NMR spectroscopy to problems in chemistry, biochemistry, and molecular biology has been revolutionary on research in those fields.

With NMR, scientists could, for the first time, study the spatial structure of molecules in solution. Physiologists could monitor the

chemical reactions in a cell or tissue under normal, abnormal or diseased conditions. Biologists could now study reactions in an intact liver, in an intact heart muscle, and in other tissues as they metabolized.

It is now possible to map, on an almost routine basis, the interior of a tissue or organ using NMR imaging. Living systems can be studied directly, for both scientific and medical purposes. NMR began as an exotic, complex, theoretical model, far removed from the real world of biology and medicine. Physicists, chemists, and biologists developed it into an important tool for understanding life processes and for developing better medical care.

As these examples dramatically illustrate, money spent on research instrumentation is an investment that increases both the quality of the science that can be pursued and the productivity and efficiency of scientists. When this equipment is accessible to university and college researchers, it also helps train graduate students.

In the past few years, we have come to realize that our Nation is underinvesting in state-of-the-art instrumentation and facilities for academic institutions. Although we do not know precisely how severe this problem is, we do know that the problem is large and involves most areas of science and engineering and most of our major research universities.

In 1982, the Foundation conducted a study of research equipment at 43 universities that rank among the largest academic R&D performers in the Nation. The study focused on equipment costing between \$10,000 and \$1 million in engineering, computer sciences, and the physical sciences. We will undertake a second study this summer to collect comparable data for the biological, agricultural, and environmental sciences.

Several of our findings were startling. Fully 25 percent of the equipment in these fields was obsolete and only 16 percent was considered state of the art. An average of 18 investigators used each instrument system. Sixty-four used each computer.

The Federal Government's importance in providing the research instrumentation base in these universities is great. Two-thirds of all of the equipment used in 1982 was acquired with partial or full Federal support.

The aggregate purchase price of the instrumentation in active use in this sample of universities was \$699 million. The estimated replacement cost was just under \$1 billion.

These findings illustrate why, for the fourth year in a row, we have given expanded support for research instrumentation one of the highest priorities in the Foundation's budget request. Each of the Foundation's programs addresses the problem of research instrumentation and facilities, with an eye to its own particular requirements and needs.

The most general type of support is providing a single investigator with the instrument required for his project. The equipment is most frequently off the shelf and costs an average of \$15,000. More expensive single instruments for multiuser, multigroup projects may be requested through special programs.

Such instruments, with an average cost of \$90,000, may also be provided through university-based centers and facilities, such as the materials research laboratories, the coordinated experimental

research program in computer science which I mentioned yesterday, university astronomical observatories, or the multidisciplinary engineering research centers planned for fiscal year 1985. Some of this equipment is developed and some is off the shelf.

In my testimony yesterday, I also mentioned our regional instrumentation facilities program, which makes costly instrumentation accessible to a large number of qualified users, including those at smaller institutions and commercial enterprises.

Finally, the Foundation funds a limited number of large-scale facilities, such as Kitt Peak National Observatory, the academic oceanographic fleet, the National Center for Atmospheric Research, and the CESR accelerator at Cornell.

Mr. Chairman, you will be pleased to know that, in addition to our direct programmatic efforts, the Foundation is taking a number of steps to improve the research instrumentation and facilities base in our universities and colleges so that we can meet our scientific and technological needs through the eighties and beyond.

In the fall of 1983, we initiated support of a project by the Association of American Universities and the National Association of State Universities to examine a wide range of issues, including: the use of debt financing to purchase research equipment; methods for improving the procurement, management, use, operation, and maintenance of equipment; and opportunities for changing Federal regulations which impose unnecessary and costly restrictions on the procurement or use of equipment.

We believe that the results of this study will be highly beneficial to universities, as well as to the Federal Government, allowing us to get more and better science and training for our money.

In addition, an interagency steering committee, with participation from the Department of Defense, the National Institutes of Health, the Departments of Energy and Agriculture, and the NSF, is currently planning a study of university research facilities.

Let me now turn to the Foundation's plans for providing academic researchers access to supercomputers in fiscal year 1985. Computers have been used as important scientific tools for almost 30 years, but they are approaching such sophistication and speed that we are at the threshold of major new breakthroughs in our ability to analyze and model and thus understand complex natural and manmade phenomenon.

Scientists and engineers in some disciplines extensively use the computational and modeling capabilities of this new generation of supercomputers. However, supercomputers can potentially affect every discipline of science and engineering and every university engaged in scientific research.

Nature is very complex, Mr. Chairman, and even our very best computers are still unable to deal adequately with that complexity or, for that matter, the complexity of manmade products and activities. Clearly, then, we have our work cut out for us, as this committee and the Congress recognized last year when you urged the Foundation to take a leadership role in responding to the possibilities of the "computational revolution."

There is no doubt in my mind, Mr. Chairman, that industry's ability to solve its problems will depend very much on upgrading the training and computational capabilities of our universities and

colleges and expanding support of basic engineering and scientific research on computers and information processing.

There is a broad community of scientists and engineers engaged in computational activity of one kind or another throughout private industry, the academic community, and our national laboratories. At present, the research community is fragmented.

We must overcome this fragmentation. Everyone engaged in computation faces common problems, including limitations on the availability of advanced computational technology, an inadequate supply of trained manpower, low software productivity, and communications barriers among working groups.

The Foundation has reviewed and developed its programs in response to these problems. Our major continuing objectives are: To encourage the widest possible participation of scientists and engineers in the design of our efforts; and to give priority to mechanisms which will promote cooperation and the exchange of information and resources among all parts of this diverse computational community.

In April 1983, the Foundation organized an internal working group on computers for research to help develop appropriate courses of action for the Foundation. Building on an earlier report from the panel on large scale computing in science and engineering, the members of this internal group drew on their own experiences and estimated the needs and opportunities in various areas, consulting with scientists in their respective disciplines, meeting with NSF advisory panels, and reviewing earlier studies. I also want to underline the fact that this Foundation review was and is conducted within a larger Federalwide examination of policies to develop and use supercomputers.

In May, participants in an NSF workshop, representing a wide spectrum of disciplines from academia, industry, and Government research labs, were asked to consider potential requirements in four areas: Large-scale computing capacity, new computing capability, local facilities, and networks.

There was virtually unanimous agreement that important science is not being done because academic scientists and engineers have limited access to computational resources. Workshop participants also recognized a kind of "chicken and egg" problem: Needs for access to supercomputers in a variety of disciplines are not well specified or understood; yet it is likely that they will never be identified fully until scientists have much better access than at present.

Workshop participants also agreed that local facilities must be significantly enhanced for a balanced response to these new computational opportunities. Supercomputer access should be managed as a scarce resource, and any calculation not requiring this advanced capability should be performed on smaller computers.

Finally, workshop participants agreed that substantially enhanced scientific networks, linking many diverse research communities to each other and to computational facilities, are extremely important. For one thing, an effective communications network will encourage the broad sharing of ideas and experiences among researchers and help to overcome some of the fragmentation which presently exists.

The Foundation's programs for fiscal year 1984 and fiscal year 1985 were established initially within the recommendations of this workshop. Since then, an Advisory Committee for Advanced Scientific Computing has been established to provide additional advice and guidance to the program as it evolves. Composed of 15 distinguished scientists and engineers, representing a broad range of experiences, disciplines, and computing expertise, this committee met for the first time last month to review our plans and progress and evaluate our proposed program directions.

In fiscal year 1984, our first order of business is to arrange for large blocks of time at existing computational sites for NSF grantees whose research will benefit from such access. This priority is consistent with the belief that such increased access can be done now and is important.

We plan to initiate an additional phase of our long-range program by the end of fiscal year 1984 with the selection of a scientific and technical organization to manage the design, development and eventual implementation of a new computational network. This network will efficiently link researchers with each other and with existing and new supercomputer centers and their trained staffs. Support for the initial stages of this network, about \$5 million, will be provided from our fiscal year 1985 request.

Depending on the final cost of the blocks of time which we purchase in fiscal year 1984 and fiscal year 1985, it is possible that we may have sufficient resources within our request to consider the initial phase of support for a new supercomputer user facility, either by adding on to an existing facility or by beginning a new center. I shall keep this committee fully informed as our plans in this regard develop.

In conclusion, Mr. Chairman, I believe that it is absolutely imperative for our Nation's universities and colleges to be at the cutting edge of scientific and technical developments. As I have said several times over the past 2 days, these are the institutions which prepare future generations of scientists and engineers. The research conducted in them also provides the knowledge base from which new technologies and new understandings of natural and social processes will emerge.

Scientific research instrumentation and computers are at the very heart of research and training. Improvements in them open the way for new discoveries, new understanding, new processes. For these reasons, our fiscal year 1985 request continues the high priority we have placed on upgrading and increasing access to quality instrumentation. It also expands our support of advanced computing facilities.

We have made a conscious effort to keep the planning for our program on advanced computational facilities open and flexible. It is a new, emerging area of great importance. It is based on a rapidly evolving set of technologies. The research community is fragmented. It is very important to encourage broad participation at each step of the way. While we are designing a program, we must also achieve and maintain a consensus on priorities and directions.

Thank you, Mr. Chairman. I will be pleased to answer any questions.

[The statement follows:]

STATEMENT OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. Chairman and members of the committee, I am pleased to be back for the second day of hearings on the Administration's Budget Request for the National Science Foundation. Today I will focus on a topic which I know is of great interest and concern to this Committee and the Congress: access to modern research instrumentation and advanced computers for scientists and engineers.

Mr. Chairman, investigators in almost every field of science and engineering depend more and more on research instrumentation and computers to conduct leading-edge research. The quality and availability of these sophisticated tools have a major impact on the productivity and efficiency with which researchers work.

Research instrumentation—whether it is the mass spectrometer of the chemist, the electron microscope of the biologist, the radio telescope of the astronomer, or the diamond-anvil pressure cell of the geophysicist—is an extension of a scientist's senses when he or she asks questions of nature. Instruments are the "eyes," "ears," and "finger tips," through which a researcher experiences nature and discovers information.

Modern computers are powerful tools which enable the scientist and engineer to manipulate and interpret unimaginable amounts of complex data. This makes it possible for them to construct and manipulate models which simulate the behavior of phenomena in fields as diverse as economics and atmospheric science.

The Foundation's Budget Request for fiscal year 1985 places a high priority on strengthening the research instrumentation base in our Nation's universities and colleges. These institutions conduct most of our fundamental scientific and engineering work and train our future engineers and scientists. Our request also includes a significant expansion of support of computer networking and research time on so-called "Supercomputers." This is in recognition of the growing importance of efficient access to such advanced computational facilities for training our present and future scientists and engineers and for laying the groundwork for the scientific and technological breakthroughs we need if our country is to stay economically competitive in the world marketplace.

Let me begin my discussion of our fiscal year 1985 proposals with two brief examples of improvements in instrumentation. These examples illustrate the need for increased support for research instrumentation.

INSTRUMENTATION AND RESEARCH: NMR'S AND PRESSURE CELLS

Since all natural phenomena are related, the results of research in one field—say physics—often affect other disciplines in unexpected and revolutionary ways. Such interactions often result from the development of an instrument.

A prime example of this is the phenomenon of nuclear magnetic resonance (NMR), investigated by the physicists Bloch at Stanford and Purcell at Harvard, both of whom received the Nobel Prize for their work. Bloch and Purcell were working, independently, on an esoteric problem—the behavior of substances in a magnetic field when they are irradiated by radio frequency waves. Using classical and quantum mechanics, they predicted and observed that water, when subjected to these conditions, absorbed energy. Building on this, scientists realized that the absorption of energy has characteristic of the elements making up the molecule and its local environment. In the case of the original experiment, the absorbing element in the water molecule was hydrogen—an element widely found in natural systems.

Soon, the phenomenon of nuclear magnetic resonance, originally studied for its own sake, was developed into a nuclear magnetic resonance spectrometer—a tool for probing the nature of the molecules themselves. Without exaggeration, the application of NMR spectroscopy to problems in chemistry, biochemistry and molecular biology has been revolutionary on research in those fields.

Before the development of NMR, scientists used X-ray diffraction to study the three dimensional structure of molecules. X-ray diffraction was, however, limited to molecules in the solid state. With NMR, scientists could for the first time study the spatial structure of molecules in solution. Physiologists could monitor the chemical reactions in a cell or tissue under normal, abnormal, or diseased conditions. For example, they could follow the synthesis or degradation of adenosine triphosphate, the source of energy in muscle action in living tissue. Biologists could now study reactions in an intact liver, intact heart muscle, and in other tissues as they metabolized.

It is now possible to map, on an almost routine basis, the interior of a tissue or organ using NMR imaging—somewhat analogous to CAT-scanning. Living systems can be studied directly both for scientific and medical purposes. NMR began as an exotic, complex, theoretical model far removed from the real world of biology and

medicine. Physicists, chemists, and biologists developed it into an important tool for understanding life processes and for providing better medical care.

Let me move from molecules and cells to the global phenomena studied by Geoscientists. Plate tectonics theory, established two decades ago using detailed magnetic mapping of the ocean floor and analysis of ocean sediments and rock, was a general theory that allowed geoscientists to interpret a wide variety of previously enigmatic observations about the earth's crust and ocean basins. Geoscientists have since expanded their understanding of many details and mechanisms implied by this theory.

Initially much geological knowledge was based on inferences from field work—magnetic maps, core samples, and measurements of seismic wave velocities through the earth's crust. Today, instruments such as diamond-anvil pressure cells, ion microprobes, and high resolution transmission electron microscopes allow earth scientists to study geological phenomena in the laboratory as well. This is vital for further exploration and development of plate tectonics theory.

In the case of diamond-anvil pressure cells, for example, material comparable to that found in the earth's interior is placed between faceted-diamond press faces and subjected to extremely high pressures. When heated with a laser, the sample experiences pressure-temperature conditions thought to exist within the earth. Because the diamonds are transparent, geoscientists can use a microscope to observe changes of state—phase transitions—in the material. By correlating these laboratory observations with knowledge obtained from seismic wave studies, geoscientists are able to understand the composition, structure and dynamics of the earth's mantle much better.

NATIONAL INVESTMENT IN RESEARCH INSTRUMENTATION

As these examples dramatically illustrate, money spent on research instrumentation is an investment that increases both the quality of the science that can be pursued and the productivity and efficiency of scientists. When this equipment is accessible to university and college researchers, it also helps train graduate students.

In the past few years, we have come to realize that our nation is underinvesting in state-of-the-art instrumentation and facilities for academic institutions. Although we don't know precisely how severe this problem is, we do know that the problem is large and involves most areas of science and engineering and most of our major research universities.

In 1982, the Foundation conducted a study of research equipment at 43 universities that rank among the largest academic R&D performers in the Nation. The study focused on equipment costing between \$10,000 and \$1.0 million in engineering, computer science, and the physical sciences. We will undertake a second study this summer to collect comparable data for the biological, agricultural, and environmental sciences.

Several of our findings were startling.

Fully 25 percent of the equipment in these fields was obsolete, and only 16 percent was considered "state-of the art."

An average of 18 investigators used each instrument system; 64 used each computer.

The Federal government's importance in providing the research instrumentation base in these universities is great: Two-thirds of all of the equipment used in 1982 was acquired with partial or full Federal support.

The aggregate purchase price of the instrumentation in active use in this sample of universities was \$699 million. The estimated replacement cost was just under \$1.0 billion.

NSF SUPPORT OF INSTRUMENTATION

These findings illustrate why, for the fourth year in a row, we have given expanded support for research instrumentation one of the highest priorities in the Foundation's budget request. In fiscal year 1985, support of instrumentation and facilities will reach an estimated \$237.0 million, an increase of 20.3 percent over fiscal year 1984.

Each of the Foundation's programs addresses the problem of research instrumentation and facilities with an eye to its own particular requirements and needs. This permits maximum flexibility in fulfilling the equipment needs in each discipline in terms of size, cost, and type of support.

The most general type of support is providing a single investigator with the instrument required for his project. The equipment is most frequently off-the-shelf and costs an average of \$15,000 to \$18,000. More expensive, single instruments for

multi-user, multi-group projects may be requested through special programs such as the Astronomical, Biological, Chemical, and Materials Research Instrumentation programs.

Such instruments, with an average cost of \$90,000, may also be provided through university-based centers and facilities such as the Materials Research Laboratories, the Coordinated Experimental Research program in computer science I mentioned yesterday, university astronomical observatories, or the multidisciplinary engineering research centers planned for fiscal year 1985. Some of this equipment is developed, and some is off-the-shelf. We estimate that approximately \$122 million of our planned total obligations for instrumentation in fiscal year 1985 will be obligated through the single user or multi-user facilities. I anticipate that over \$6.0 million of this will go to support equipment in predominantly undergraduate institutions.

In my testimony yesterday, I also mentioned our Regional Instrumentation Facilities program which makes costly instrumentation accessible to a large number of qualified users, including those at smaller institutions and commercial enterprises. This is still another way we respond to instrumentation needs in the scientific community.

The Foundation's program in physics illustrates another type of support. Through this program we support user facilities such as the Cornell Electron Storage Ring; the Indiana University Cyclotron Facility, including a "Cooler" ring; and the superconducting cyclotron at Michigan State University. These and other national and international research facilities are available for experimental work supported by NSF.

Finally, the Foundation funds a limited number of large-scale facilities such as Kitty Peak National Observatory, the academic oceanographic fleet, and the National Center for Atmospheric Research. We estimate that over 2,000 astronomers a year use the instrumentation and facilities supported by the NSF at its national astronomy centers.

ADDITIONAL STEPS TO ENHANCE INSTRUMENTATION AND FACILITIES BASE

Mr. Chairman, you will be pleased to know that, in addition to our direct programmatic efforts, the Foundation is taking a number of steps to improve the research instrumentation and facilities base in our universities and colleges so that we can meet our scientific and technological needs through the 80s and beyond.

In the Fall of 1983, we initiated support of a project by the Association of American Universities and the National Association of State Universities to examine a wide range of issues including:

- The use of debt financing to purchase research equipment;
- Methods for improving the procurement, management, use, operation, and maintenance of equipment; and
- Opportunities for changing Federal regulations which impose unnecessary and costly restrictions on the procurement or use of equipment.

We believe that the results of this study will be highly beneficial to universities as well as to the Federal government, allowing us to get more and better science and training for our money.

An interagency steering committee with participation from the Department of Defense, the National Institutes of Health, the Departments of Energy and Agriculture, and the NSF is currently planning a study of university research facilities. Its objective is to understand the status of existing facilities used for conducting scientific and engineering research and to estimate future needs for construction, remodeling and refurbishment.

ADVANCE COMPUTATIONAL RESOURCES

Let me now turn to the Foundation's plans for providing academic researchers access to supercomputers in fiscal year 1985.

Science is undergoing a structural change. In addition to the two broad methodologies of experimental and theoretical science, we now have computational and information science. Computers have been used as important scientific tools for almost 30 years, but they are approaching such sophistication and speed that we are at the threshold of major new breakthroughs in our ability to analyze and model—and thus understand—complex natural and man-made phenomena.

Scientists and engineers in some disciplines—atmospheric sciences, and plasma physics, for example—extensively use the computational and modeling capabilities of this new generation of supercomputers. However, supercomputers can potentially affect every discipline of science and engineering and every university engaged in scientific research. Industry too is fast becoming dependent on large-scale, high-

speed computation to simulate air flow around aircraft parts, develop new drugs, or construct three-dimensional models of underground oil and water movements to exploit oil fields.

Nature is very complex, Mr. Chairman, and even our very best computers are still unable to deal adequately with that complexity or, for that matter, the complexity of man-made products and activities. For example a typical liquid sample contains 10^{23} atoms (a 1 followed by 23 zeroes); the simulation of a liquid today on the largest computer is limited to a few thousand atoms. This sample of atoms is too small for accurate descriptions of liquids because of the resulting large statistical uncertainties. Similarly, the simulation of the airflow around an entire airplane in flight now takes several months.

Clearly, then; we have our work cut out for us as this committee and the Congress recognized last year when you urged the foundation to take a leadership role in responding to the possibilities of the "computational revolution." There is much to do. It is important that we begin now, today, if we are to solve the scientific, engineering, and technological challenges which block us from preparing scientists and engineers for the transition to computation and information science which is taking place.

There is no doubt in my mind, Mr. Chairman, that industry's ability to solve its problems will depend very much on upgrading the training and computational capabilities of our universities and colleges and expanding support of basic engineering and scientific research on computers and information processing.

There is a broad community of scientists and engineers engaged in computational activity of one kind or another throughout private industry, the academic community, and out national laboratories. The computer industry supports large-scale scientific computing through its marketing and product development efforts. Supercomputers are only a small part of the total industrial effort.

At present, the research community is fragmented into separate professional associations like the society for Exploration Geophysics or the Computational Chemistry Division of the American Chemical Society; user groups for different computing systems; groups located in academia, industry, and government laboratories; and of course, user groups in various disciplines—computer science, atmospheric science, chemistry, physics, and electrical or mechanical engineering. We must overcome this fragmentation. Everyone engaged on computation faces common problems including limitations on the availability of advanced computational technology, an inadequate supply of trained manpower, low software productivity, and communication barriers among working groups.

The Foundation has reviewed and developed its programs in response to these problems. Our major, continuing objectives are to:

Encourage the widest possible participation of scientists and engineers in the design of our efforts; and

Give priority to mechanisms which promote cooperation and the exchange of information and resources among all parts of this diverse computational community.

In April, 1983, the foundation organized an internal working group on computers for research to help develop appropriate courses of action for the foundation. Building on an earlier report from the panel on large-scale computing in science and engineering, the members of this internal group drew on their own experiences and estimated the needs and opportunities in various areas, consulting with scientists in their respective disciplines, meeting with NSF advisory panels and reviewing earlier studies. I also want to underline the fact that this foundation review was and is conducted within a larger, Federal-wide examination of policies to develop and use supercomputers. New generations of highly advanced computational facilities are a challenge to industry and government as well as to the academic scientific and engineering community which the foundation addresses. It is a challenge which none of us can afford to ignore.

In May, participants in an NSF workshop representing a wide spectrum of disciplines from academia, industry and government research labs, were asked to consider potential requirements in four areas:

- Large-scale computing capacity;
- New computing capability;
- Local facilities; and
- Networks.

There was virtually unanimous agreement that important science is not being done because academic scientists and engineers have limited access to computational resources. Workshop participants also recognized a kind of "chicken and egg" problem: The need for access to supercomputers in a variety of disciplines are not

well specified or understood, yet it is likely that they will never be identified fully until scientists have much better access than at present.

In many cases, the academic scientific and engineering community will be learning and exploring during the early stages of any supercomputer program, inventing new ideas and redefining old ones as they interact with each other and as they use and develop supercomputer software and hardware. As this learning and exploring proceeds, there is little doubt that the need for large-scale computing capacity in universities will grow substantially. Given the rate at which such technology improves and changes, opening up still new opportunities for exploration, we may never catch up. In fact, if we are doing things right, we should never catch up with the need!

Workshop participants also agreed that local facilities must be significantly enhanced for a balanced response to these new computational opportunities. Supercomputer access should be managed as a scarce resource, and any calculation not requiring this advanced capability should be performed on smaller computers. In fact, most scientific calculations will not require supercomputers.

Finally, workshop participants agreed that substantially enhanced scientific networks linking many diverse research communities to each other and to computational facilities are extremely important. For one thing, an effective communications network will encourage the broad sharing of ideas and experiences among researchers and help overcome some of the fragmentation which presently exists. Its development, in conjunction with the growth of supercomputer capability, will push the state-of-the-art in software, network design, equipment and network management, and give rise to new, unexpected discoveries. These discoveries will be used to design future computational systems well beyond our capabilities today. Computer networks, properly designed and managed, will bring about efficient, remote access to these scarce computational resources. These three things will enhance substantially the Foundation's investment.

The Foundation's programs for fiscal year 1984 and fiscal year 1985 were established initially within the recommendations of this Workshop. Since, then, an Advisory Committee for advanced Scientific Computing has been established to provide additional advice and guidance to the program as it evolves. Composed of fifteen distinguished scientists and engineers representing a broad range of experiences, disciplines, and computing expertise, this Committee met for the first last month to review our plans and progress and evaluate our proposed program directions.

In fiscal year 1984, our first order of business is to arrange for large blocks of time at existing computational sites for NSF grantees whose research will benefit from such access. Up to \$6.0 million has been set aside for this purpose so that computer service can be made available to scientists and engineers in all the disciplines represented in the NSF. This priority is consistent with the belief that such increased access can be done now and is important—both to pursue work which can only be done on such facilities and to explore the potential use of supercomputers in a wide range of disciplines.

In the fall of 1983, the Foundation issued a Solicitation inviting proposals which offered blocks of time for use by NSF researchers. Seven were received and have been reviewed by staff and the new Advisory Committee at its first meeting. We are now in the process of reviewing these proposals and expect to make a decision sometime later this Spring. The plan is to arrange for up to the equivalent of one supercomputer for use by researchers.

We are requesting \$20.0 million for the total program in fiscal year 1985. While our plans are still evolving, we anticipate using up to half of this amount for supercomputer access by researchers.

We plan to initiate an additional phase of our long-range program by the end of fiscal year 1984 with the selection of a scientific and technical organization to manage the design, development, and eventual implementation of a new Computational Network. This Network will efficiently link researchers with each other and with existing and new supercomputer centers and their trained staffs. Until this Network is complete, or at least fairly far along, remote access will be limited to relatively slow telephone lines, and many investigators will have to be on site in order to conduct their research. Support for the initial stages of this Network, about \$5.0 million, will be provided from our fiscal year 1985 request.

The balance of the requested \$20.0 million will be used to provide local equipment needed to access the Computational Network and to support experiments with broad-band communications.

Depending on the final cost of the blocks of time which we purchase in fiscal year 1984 and FY 1985, it is possible that we may have sufficient resources within our Request to consider the initial phase of support for a new supercomputer user facili-

ty either by adding on to an existing facility or beginning a new center. I shall keep this Committee fully informed as our plans in this regard develop.

CONCLUSION

In conclusion, Mr. Chairman, I believe that it is absolutely imperative for our Nation's universities and colleges to be at the cutting edge of scientific and technical developments. As I have said several times over the past two days, these are the institutions which prepare future generations of scientists and engineers. The research conducted in them also provides the knowledge base from which new technologies and new understandings of natural and social processes will emerge.

Scientific research instrumentation and computers are at the very heart of research and training. Improvements in them open the way for new discoveries, new understanding, new processes. For these reasons, our fiscal year 1985 Request continues the high priority we have placed on upgrading and increasing access to quality instrumentation. It also expands our support of advanced computing facilities.

We have made a conscious effort to keep the planning for our program on advanced computational facilities open and flexible. It is a new, emerging area of great importance. It is based on a rapidly set of technologies. The research community is fragmented. It is very important to encourage broad participation at each step of the way. While we are designing a program, we must also achieve and maintain a consensus on priorities and directions.

Thank you, Mr. Chairman, I will be pleased to answer any questions.

Senator GORTON. We will proceed to the balance of the panel. We will proceed to Dr. Lane. Dr. Lane, your entire written statement will be included in the record as if read. You may proceed and summarize as you wish.

Dr. LANE. Thank you, Mr. Chairman.

I am very pleased to have this opportunity to discuss with you today the needs of the Nation's science and engineering researchers for access to advanced computing capability and to comment on the National Science Foundation's ability to address these needs.

I appear before you today not as an expert in computer science or technology but as a research scientist who has spent two decades trying to unravel some of the problems of atomic and molecular physics using quantum mechanics. Computing is very important to me personally and to my community. In my field, as in many other fields of science, there are problems that require the most powerful computers of today, the so-called supercomputers. There are many other problems that require 100 to 1,000 or more times the current capability and therefore, that must await future research developments in computer science and technology.

In the meantime, much of the important research that can be done now with today's advanced computers is not being done, is due largely to inadequate access by our scientists to these advanced facilities. They are too expensive, relatively inaccessible, and often inadequately configured in terms of memory or other aspects of the facility.

European and Japanese scientists do not seem to have the same problems, at least not to the same extent. Some U.S. scientists, tend to go abroad to find affordable computing, while some of the machines we have in the United States sit idle much of the time, in large measure due to their expense.

A colleague of mine recently visited Japan. He wrote me saying that many of the Japanese scientists who work in his field of atomic physics have essentially unlimited access to machines in Japan which are comparable with today's CRAY 1 or CYBER 205.

Not only that. In at least two of these laboratories there are plans to upgrade to more powerful machines shortly.

Indeed, he suggested there is a policy in these laboratories to try to upgrade every year and a half to 2 years to make sure that science moves along as well as it can. He finds it very difficult to compete on similar research under these circumstances.

The National Science Foundation, recognizing these needs, has launched the advanced scientific computing initiative. An advisory committee has been formed, and I am very pleased to be its first chairman. The names of all the other members of the committee are included in the written testimony that has been submitted to your committee, Mr. Chairman.

At its first meeting, the committee emphasized that a major goal of the Foundation initiative should be to promote cooperation and exchange of resources among all members of the scientific and engineering computing community: (1) by establishing a national network for all disciplines of science and engineering, whatever their support base, wherever they come from; (2) by developing closer ties among universities and computer vending companies; and (3) by establishing interdisciplinary groups at universities which bring together computer scientists and other sorts of scientists, engineers, and others to collaborate on common computational problems, to share software, and to build a common and shared equipment base.

It is clear that support for this kind of ambitious national program must come from all sources. However, the feeling is that a bold National Science Foundation initiative could set in motion a synergism that would have far greater impact than the Foundation funding alone could possibly achieve. But a first step, which is currently under way, is to move rapidly to provide access to currently available advanced computer resources for those NSF-supported scientists and engineers whose work depends critically on these large-scale computer facilities.

The NSF has budgeted \$6 million in 1984, and has requested \$20 million in 1985, for this special initiative, as you have heard previously. The advisory committee has already had some difficulty recommending an appropriate plan of action, because the available funds seem so short of the perceived needs. In my personal view, several times the amount included in 1985 could be effectively used to accelerate this most vital national program.

As you mentioned, Mr. Chairman, Dr. Kenneth Wilson, a Nobel prizewinner in physics at Cornell, was quoted in yesterday's Washington Post as recommending a figure of \$100 million. Well, I do not know if \$100 million is exactly the right amount, but the advisory committee agreed that the need was of this order.

Whatever the amount, \$60 million, \$80 million, \$100 million that is felt to be appropriate, the important issue is one of starting a carefully planned program with substantial growth so that the signal goes out to the university, Government, and industrial communities that we are serious about this initiative and we intend to make these advanced computer facilities available.

However, the fiscal year 1985 requested funding level does make possible a long overdue startup with the establishment of an adequate initial network and the provision of computing time on these

advanced systems. In March, Mr. Chairman, the committee will meet to make recommendations on plans for the network selection of the computer vendors who will provide the services, and possible support of other activities that are consistent with the NSF initiative.

Personally, I am very excited about the program, as is the committee. We are optimistic that the NSF initiative will lead to qualitatively new and exciting research results in virtually all fields of science and engineering.

Mr. Chairman, that concludes my summary remarks. I will be pleased to answer any questions later that you may have.

[The statement follows:]

STATEMENT OF DR. NEAL F. LANE, PROFESSOR OF PHYSICS, RICE UNIVERSITY

Mr. Chairman and Members of the Committee, I am Neal Lane, Professor of Physics at Rice University, and chairman of the National Science Foundation's Advisory Committee for Advanced Scientific Computing Resources. I am honored and pleased to have this opportunity to appear before you to discuss the needs of the nation's research scientists and engineers for access to advanced computer capability, and some efforts underway to address these needs.

I appear before you today not as an expert in computer technology, but as a research scientist who has spent two decades applying basic quantum physics to fundamental and applied problems of atomic, molecular, and optical (AMO) physics.

Research in AMO physics deals with the most basic questions regarding the makeup of atoms and molecules and their behavior during collisions or when exposed to light, or other electric or magnetic fields. Because of the complexity of such systems, and of the quantum theory which determines their behavior, the power of available computers has had enormous influence on the rate of scientific progress.

In this field of science, as in many others, there are important scientific questions where progress requires the most advanced computing resources the so-called supercomputers of today. And, beyond these lies more far-reaching questions that will require a capability thousands of times that of today's supercomputers, and therefore that must await future developments in computing science and technology.

In the meantime, much of the important research that can be done using today's computer technology is not being done, either because of a lack of access to advanced compute resources or a lack of sufficient knowledge to take full advantage of the power of these resources, or both. Some U.S. scientists must go abroad to gain access to affordable computing while some of the few supercomputers available in this country sit idle a significant fraction of the time. Many scientists and engineers whose research could benefit enormously from the use of advanced computing methods have little or no access to these facilities.

The scientific opportunities and barriers to progress have been analyzed and well documented in a number of government studies and reports. However, as in all questions of research, it is the unexpected and unplanned that often has the most profound and lasting impact on science and on our culture. Certainly, we should admit that attempts to predict the full effects of future computing capabilities on science, engineering and advanced technology are likely to fall far short of the mark.

The National Science Foundation, recognizing the critical needs of the science and engineering research communities for advanced computing capability, has launched a national Advanced Scientific Computing initiative to make the most advanced computers available in the U.S. today accessible to NSF-supported scientists and engineers, while continuing to provide for more modest computing needs, and for research in computer sciences and in other applications of computer technology.

An Office for Advanced Scientific Computing has been established within the NSF, and an Advisory Committee for Advanced Scientific Computing Resources has been appointed to assist the NSF with the future planning and implementation of the program. I am pleased to serve as the committee's first chairman. The other members of the committee are: Dr. Joan M. Centrella, University of Texas; Ms. Margaret A. Drake, National Center for Atmospheric Research; Dr. Oscar N. Garcia, University of South Florida; Dr. James F. Gilbert, University of California at San Diego; Dr. Anthony C. Hearn, Rand Corporation; Dr. Cecil E. Leith, Jr., Lawrence Livermore National Laboratory; Dr. Cyrus Levinthal, Columbia University;

Dr. David Nagel, NASA Ames Research Center; Dr. Steven A. Orszag, Mass. Inst. of Technology; Dr. Christopher A. Sims, University of Minnesota; Dr. Mark A. Stadtherr, University of Illinois; Dr. Frank H. Stillinger, AT&T Bell Laboratories; Dr. Kenneth G. Wilson, Cornell University; and Mr. Joe Billy Wyatt, Vanderbilt University.

At its first meeting, held on Jan. 30 and 31, 1984. The committee members present affirmed the principal findings of the internal NSF Working Group on Computers for Research, as contained in the NSF report: "A National Computing Environment for Academic Research." In facing the difficult task of advising the NSF on the allocation of \$6M in fiscal year 1984, and the \$20M in fiscal year 1985 requested for this program, the committee was struck by the magnitude of the gap between need and resources. Recognizing that even with sizeable increases in future budgets, the gap is likely to remain large, the committee members present issued a statement emphasizing the vital importance of full cooperation between the federal government, Universities, and industry. Only by building and maintaining this cooperation at the highest possible levels, can the nation hope to be effective in the use of advanced computing resources in scientific and engineering research and education, and in the development of future computer technologies that are competitive with those of other nations.

Let me take a few moments to focus on several points made in the statement.

SCIENCE AND ADVANCED SCIENTIFIC COMPUTING

The potential impact of advanced computing technology on future science is of such magnitude that many scientists predict a structural transition from two broad methodologies to three, namely from experimental and theoretical science, to include the additional category of computational and information science. The transition is already apparent in engineering.

New scientific opportunities, including the direct dynamical modeling of complex physical systems, develop rapidly in response to major advances in computer system capability, for example, factors of ten improvement in speed, memory size, or peripheral storage. It is expected that the new opportunities for scientific inquiry and industrial applications made possible by large-scale computation will feed back into global scientific and engineering activity in theory, experiment, and computation.

Industry is becoming increasingly dependent on large-scale computation to help design products that are competitive in world markets. These needs for breakthroughs in research and for trained manpower should swell total scientific activity.

AN INTEGRATED SCIENCE AND ENGINEERING COMMUNITY

Scientists and engineers who are engaged in advanced computational activity are scattered throughout private industry, universities, and national laboratories. And yet, they face a common set of problems, for example, low software productivity, inadequate access to advanced computer technology, and a lack of trained manpower.

Therefore, a major goal of the NSF Advanced Scientific Computing initiative should be to promote cooperation and exchange of resources among all members of the scientific and engineering computational community. It should also have the objective of establishing university research and advanced training as a full-fledged part of community activity.

If quality research and education in advanced computing is to be possible, it is vital that the computing technology available to universities be equal to that available to the rest of the community. In fact, whenever possible, it is desirable that new technology go first to the universities so that students can be trained in its use; in this way, trained manpower becomes available simultaneously with commercial introduction of the technology. This should be done with a full line of products, from desk-top workstations, to specialized processors, to supercomputers.

Closer cooperation among members of the scientific and engineering computational community requires concrete steps by the NSF. The most effective means known for accomplishing this ambitious goal of wide interdisciplinary communication is through the use of computer networks.

The NSF should give immediate priority to a national network for all disciplines of science and engineering, starting with the university community supported by the NSF, but seeking as rapidly as possible to extend the coverage of computer communication networks to the full scientific and engineering community in industry and government laboratories as well. An early version of this national network can and should be established immediately to provide access to advanced computer systems for NSF supported scientists and engineers.

A second important form of cooperation will result from the development of ties between universities and computer vendors. The universities can supply researchers with expertise in a wide range of areas from circuit design to specific scientific applications. Students can be trained on prototype technologies made available prior to commercial production. And the use of new machines by students and faculty researchers can provide invaluable critical reviews of a particular product's strengths and weaknesses.

In order that such cooperation be mutually advantageous, the NSF should continue to cooperate with universities to develop guidelines to protect both the academic freedom of the university participants and the proprietary rights of the industrial partners in such ventures.

A third form of cooperation involves interdisciplinary groups at individual universities, bringing together scientists, engineers and others to collaborate on common computational problems, share software, and to build a common equipment base for their research.

The NSF is encouraged to consider the model of interdisciplinary groups within single universities or university consortia to be of equal if not higher priority than single discipline approaches to meeting the need for advanced computing capability.

These forms of cooperation, and others that will naturally develop, will maximize the impact of advanced computer technology on science and engineering research and education, and on the transfer of new scientific and engineering developments and properly trained manpower into the industrial segment of the community. Support for the necessary university research and education must come from all sources. However, a bold NSF computational initiative with sufficient funds should set in motion a university and industrial synergism with far greater impact than NSF funding could possibly achieve by itself.

The NSF is encouraged to do everything possible to see that funding for this initiative in advanced scientific computing reaches the threshold level to achieve full cooperation from the rest of the community. Only in this way can the full potential of advanced computing, to compete on equal footing with experimental and theoretical science, be achieved.

REQUIREMENTS FOR PROGRESS

Barriers to progress exist in many forms. The NSF Advanced Scientific Computing initiative, by providing an immediate response to the needs of the NSF supported research scientists and engineers, should stand as a model to the wider community. In this manner, the NSF can play a leading role in removing barriers from all segments of the industry/university/national-laboratory environments so that advanced computing capability can be matched with the scientific and engineering needs on a national scale.

Requirements that warrant particular emphasis include:

(1) The NSF should insure that the arrangements being made to provide immediate access to advanced computers for NSF supported scientists and engineers guarantee quality service from the host facility, national network, and local work stations. Moreover, it is essential that sufficient time be made available on advanced computers so as to make possible a qualitative impact on the research.

(2) Faculty and student access to advanced computers, and their effective use in research and education, requires the development of an infrastructure of local university networks, superminicomputers, desk-top work stations, peripheral devices, and full software and expert personnel support. The NSF should have a special interdisciplinary program working with universities to establish this infrastructure and make it available for a full range of research and advanced educational needs, even in research areas where computing demands are not yet well established.

(3) Optimal use of advanced scientific computing capability will require full equality between remote and local access to high-performance computing systems. Thus, the NSF must confront high bandwidth networking issues so that full three-dimensional color graphics and other high-speed data transfer requirements can be met for users of a specific facility from across the U.S.

(4) Major advances in the capability of advanced computers to solve new and important science and engineering problems will require continuing research in hardware, software, and numerical analysis, as well as collaborative research involving natural scientists, engineers, and computer scientists. The NSF should support research and advanced training in these areas; it should also support efforts to achieve very high computing power on specialized architectures for special applications.

(5) Universities can be expected to contribute fully to research and education in advanced computing only if students and faculty have access to the most advanced computer technology at modest cost. For example, the availability to universities of inexpensive software-compatible versions of future supercomputers could be very valuable to the NSF initiative.

BUDGET CONSIDERATIONS

Computational and information science has the same basic dependence on equipment as does experimental science. Many scientists feel that advanced scientific computing has the potential of making major, even revolutionary, advances in science and engineering, and therefore that future funding levels of computational and information science should be roughly equivalent to those of experimental research in science and engineering.

Even for the immediate future, the recent NSF report "A National Computing Environment for Academic Research" identified a need for \$180 M/yr. for the Advanced Scientific Computing initiative. The NSF Advisory Committee for Advanced Scientific Computing Resources agrees that the need is of this order.

The NSF has budgeted \$6M in fiscal year 1984, and has requested \$20M in fiscal year 1985, for this program. The Advisory Committee has encountered difficulties in recommending an appropriate plan of action for the allocation of these funds because they fall so short of the needs. The committee affirms that the needs are real, both in research and graduate education, and that they pervade throughout all areas of science and engineering. Until adequate funding becomes available, it will be difficult to make significant progress in the full range of research and graduate education programs that require advanced computing capability.

The planned funding levels do, however, make possible a long overdue startup, with the establishment of an adequate initial national network and provision of time on available advanced computer systems. In March the committee will meet to make recommendations on plans for the initial national advanced computing network, choices of vendors to provide advanced computing services, and possible support for other activities consistent with the NSF Advanced Scientific Computing initiative.

Mr. Chairman, this concludes my prepared testimony. I will be pleased to answer any questions that you and your colleagues may have.

Senator GORTON. Thank you, Dr. Lane.

Dr. Zdanis, we will proceed to you with the same set of rules, that your entire statement and the enclosures with it will be included in the record.

Dr. ZDANIS. Thank you very much, Mr. Chairman.

I am pleased to have been asked to present today my views on the current status of the instrumentation in universities on behalf of the American Association of Universities, the National Association of State Universities and Land Grant Colleges, the American Council on Education, the Council on Governmental Relations, the Association of Graduate Schools, and the Council of Graduate Schools.

We as associations support enthusiastically the Foundation's fiscal year 1985 budget as submitted. We view its stability and its balance to be supplementary to the ongoing programs, and are very pleased to see the new initiatives that have been included in the presentations.

The proposed engineering centers and the proposed supercomputing facilities will be the focus of intense competition. That is as it should be in this country. The final judgments, we hope, will be formed in an objective manner using the peer review system, as has been traditional within the Foundation, and has not been subject to political overtones.

We understand that in the House Science and Technology Committee today will be introduced legislation to reinforce that peer

review system. We hope that this subcommittee will review that legislation at the appropriate time.

In 1980, I was privileged to be a co-investigator on the AAU report to document for the Foundation the status of instrumentation at universities. One of the major problems in establishing that study was to provide a scale against which the state of instrumentation could be judged. We chose as a comparison the state of instrumentation at commercial research laboratories, which are the competitors for the young, talented investigators that the universities have.

We found that the median age of equipment at universities was twice that of the age of equipment found in commercial and industrial laboratories. The National Science Foundation took that finding very seriously. In 1981, it organized an interagency task force to serve as the focus for attention to the instrumentation problem Governmentwide.

There has been considerable progress in the last few years especially led by the National Science Foundation and the Department of Defense in this area, but it became obvious both for that interagency task force and some of the rest of us who are concerned about instruments, that the scale of the problem was such that just looking at increased Government funding in the normal way would not be sufficient to address all of the problems. That was the root of the program to which Dr. Knapp referred in his testimony, supported by both the American Council, the Association for American Universities, the National Association for State Colleges and Land Grant Colleges, and the Council on Government Relations.

In addition to the areas to be explored that Dr. Knapp referred to, we are also going to look at the tax incentive programs which have been so beneficial to see if there are any residual barriers there. For instance, the exclusion of software which may in fact, be very important in providing additional instrumentation donations to colleges and universities.

There are some early findings, although very preliminary, about barriers that still might exist. The material that we have found from several years ago indicated that a piece of instrumentation at a midwestern university purchased under a contract by another agency could not be assigned to be used by an investigator working under a grant from the National Science Foundation, because the other agency thought it was their job to keep the instrument used only on their programs. It is that kind of barrier that we are looking at to bring to your attention and hopefully expunge so that without expenditure of additional funds we can get maximum utilization from the instruments which do exist.

The facilities question is indeed tightly linked to the instrumentation question. We recently have been privileged at Johns Hopkins to have acquired a new electron microscope. That electron microscope requires for its maximum utilization a magnetically shielded room on a vibration-free pad.

It is very difficult to go to donors to ask to have the John and Jane Doe shielded microscope facility funded in the subbasement of Fossil Hall because that is not appreciated except for the very sophisticated donor who understands the subtleties of our needs. It is more likely that John and Jane Doe would choose to support a

sculpture which would enhance the quality of the institution and be seen by every student on their way to the student union. But if one thinks it is difficult to have the facilities of an electron microscope lab refurbished, just think about the difficulties of reducing Fossil Hall to provide the air flow for all those new computers that are there, or to provide the air flow that is necessary to accommodate new regulations on hood vents, et cetera. There are very important pieces of infrastructure that are extremely tightly coupled to the instrumentation issue.

We are pleased that S. 1537 recognizes these needs in the University Research Capacity Restoration Act of 1984, and we hope that you will see your way to funding that particular legislation. Federal support for these issues, both instrumentation and facilities, is extremely important, not only because of the leverage that it provides, even if not fully funded, to require external support, either State support or private donations, but because the review system under which these awards are made give us a feeling of quality control such that it is much easier to convince other donors of the quality of your product.

That does not mean that proposals which are not funded because of lack of appropriate sums are unworthy of support, but where we do find Federal support it is much easier to get additional donations. I would like to conclude with just a statement on the supercomputers at the Applied Physics Laboratory of the Johns Hopkins University.

We have made an extensive analysis of the need for supercomputers, and have determined that there are just some areas in oceanographic modeling and VSLI modeling that we cannot participate in to the degree that we feel is necessary for us to without the use of supercomputers, and there is an attempt to require that through the normal funding channels for API. The other research scientists at Hopkins would then have part of the time available on that computer, and we hope that additional scientists from outside the institution would also avail themselves of it.

Thank you very much for the opportunity to present these views. I would be pleased to respond to questions.

[The statement follows:]

STATEMENT OF DR. RICHARD A. ZDANIS, VICE PROVOST, JOHNS HOPKINS UNIVERSITY

Mr. Chairman and members of the committee, my name is Richard Zdanis and I am vice provost of the Johns Hopkins University. You have asked me to present my views on the current status of university research instrumentation and equipment and to tell you about a new project being undertaken by three higher education associations to explore alternative solutions to these needs. The project is seeking to identify and to evaluate new approaches to acquiring, managing, and using equipment and to inform the university community of the results of these evaluations. It is a joint undertaking of the Association of American Universities (AAU), the National Association of State Universities and Land-Grant Colleges (NASULGC), and the Council on Governmental Relations (COGR). The project is being supported jointly by the National Science Foundation joined by several other leading research agencies. I am chairing an eight-member steering committee, which will provide substantive direction for the project. A list of members is attached.

I'd like to begin by stating for the record that the members of these associations are the research universities that carry out NSF research programs. We fully support the administration's fiscal year 1985 budget for the foundation. It is, we believe, a very sound investment plan, one designed to bring an important added measure of balance and stability to the University Research Enterprise. We hope

that the committee will fully and enthusiastically support NSF's investment proposals for basic science, graduate education and instrumentation programs. We also urge your support for the proposed interdisciplinary engineering centers and for the important initiatives to improve access for university researchers to advanced scientific computers. Both of these initiatives are needed. They will enhance recent efforts to ensure the future vitality of our scientific activities.

The future return on these essential investments, or course, will be determined in large part by the soundness of the decisions that the Congress and the Foundation make in the award of the funds. The proposed new engineering centers, the priority programs to improve supercomputer facilities and other programs will be the focus of intense interest and competition. That is as it should be. The funds ought to be awarded on the basis of scientific merit in open competition among all interested and qualified parties. Final judgements ought to be formed in an objective and informed manner, free from any actions by particular individuals or institutions that could serve to make the award of such funds a matter of political influence rather than the quality of the work to be done and the capacity of competing applicants to carry out the work at the highest level.

Recently the Association of American Universities, the National Association of State Universities and Land-Grant Colleges have joined others in addressing the importance of protecting and relying upon the established processes of informed peer review in the award of funds for research and research-related purposes. The statements recently adopted by the memberships of the AAU and NASULGC are attached to my statement.

1980 AAU REPORT TO NSF

Turning to the subject of the research instrumentation needs of universities, I should begin perhaps by briefly explaining for the committee how I came to be involved in the work of these associations on our subject for this morning. In 1980 I served with Dr. Laurence Berlowitz, who was then assistant vice president for academic affairs of New York University, as coinvestigator of a study project completed for NSF in behalf of the AAU. Our report, the research instrumentation needs of universities, documented the dimensions of the equipment problem in 15 leading universities by comparing their research equipment holdings with the equipment used in a number of leading commercial laboratories and major national laboratories.

We found that researchers in many universities are indeed hampered by outmoded instruments. We measured the rough dimensions of the equipment problem by comparing equipment inventories of leading university laboratories with those of two prominent commercial laboratories. As shown on the following graph, the median age of the equipment in the universities was twice that of equipment in the commercial laboratories. Because the report has presented to the committee by associations in earlier testimony, I will not discuss it further. The executive summary of the report is attached to my statement. The complete report has been provided to the staff of the committee.

In mid-1981 the National Science Foundation organized a Government-wide inter-agency working group on university research instrumentation, chaired by the Deputy Director of the Foundation. Its members were senior officials drawn from each of the six major agencies supporting research in universities. This working group has served as a vehicle for focusing high-level agency attention on the university instrumentation problem.

In the last couple of years considerable progress has been made by the NSF and by other agencies (notably the Department of Defense, which established a special 5-year \$150 million program) in providing increased investments for research equipment. It is very encouraging to see that the foundation's fiscal year 1985 request again includes priority investments for equipment. We commend Dr. Knapp and his colleagues for sustaining the equipment initiatives in the presence of difficult budgetary circumstances.

Developments such as these are encouraging signs. Alone, however, they will not adequately address the problem. Additional sustained investments are needed. As those investments are sought we also must explore for new approaches to help ensure that those investments yield the maximum scientific and technological return.

AAU/NASULGC/COGR INSTRUMENTATION PROJECT

Recognizing this fact, the NSF asked the AAU, NASULGC, and COGR to convene an ad hoc planning committee to consider whether a special effort was needed to address the following questions:

1. Does so-called debt or creative financing hold significant untapped potential for universities as a means of financing new research equipment?
2. What more can universities do to improve the way they acquire, manage, and use research equipment?
3. Can innovations made by Government and commercial laboratories be identified and adapted for use by universities?
4. Are there regulatory and policy barriers in universities or the States that can be identified and steps that can be taken to remove or reduce them?
5. Can present tax incentives for the donation of research equipment be improved to increase support from industry?
6. Are there changes that ought to be made in Federal regulations that would ease the situation?
7. Are there alternative methods of direct Federal funding that would yield a better return on Federal investment?

The planning committee recommended that the AAU, NASULGC and COGR undertake a joint project to address these questions and to disseminate the results broadly to the university community. In September 1982 The AAU, acting in behalf of the three associations, submitted a proposal to the National Science Foundation. The Foundation was instrumental in securing funding from the other five Federal agencies for support of the project. We are pleased to report that the Research Corp. also has provided a grant to assist the effort. The costs of the project, therefore, are shared among six Federal agencies, a private corporation and the three sponsoring associations. The funding arrangement itself is a clear demonstration of the broad interest in these questions across the major agencies of Government and the research community.

Phase I

The project began in November and is scheduled to be completed in February 1985. The work is planned in three phases. During phase I analysis will be conducted in six areas:

1. *The first is the role of debt financing of research equipment in sound university financial practice.*—Considerable attention is being paid in some parts of the research community to developing new, creative modes of financing the acquisition of university research equipment. The potential usefulness of such approaches is being debated intensely, but the techniques themselves often are not well understood, and experience in their use varies considerably.

This analysis will identify the various methods of debt financing. It will assess the desirability of encouraging deeper involvement by universities in their use, give the pros and cons of different financing approaches, and provide examples of what has worked, where these techniques have worked and why. The analysis also will offer suggestions to help institutions evaluate the appropriateness of these approaches in the light of their particular circumstances.

2. *The procurement, management, and use, of research equipment is the subject of the second analysis.*—Opportunities to strengthen the organization and management of university laboratories and supporting services will be identified and assessed by the second analysis. Particular attention will be paid to new methods of sharing equipment among Departments and universities. This analysis will identify barriers to sharing inherent in the nature of university research and will consider possible ways to lower such barriers. Recent experience in using advanced technology to provide remote access to high cost equipment will also be examined. Finally, the management practices of selected commercial and Government laboratories will be reviewed to seek approaches that might be adapted to the university setting.

3. *The third analysis will assess tax incentives for the donation of equipment and suggest ways to increase support from the private sector.*—The Economic Recovery Tax Act of 1981 provided new incentives designed to stimulate donations of equipment to universities by industry. Experience to date seems to indicate that this provision is having a significant and beneficial impact on the program. This analysis will evaluate the experience to date and assess opportunities to strengthen further this new incentive to corporate support.

4. *Reduction of regulatory and policy barriers in States and universities is the subject of the fourth analysis.*—A selected number of State governments and universities will be surveyed to determine whether there are policy and regulatory barriers

to improved acquisition management, and use of research equipment. Particular attention will be given to provisions in State constitutions and laws which may restrict university efforts to improve their research laboratories. Some States, for example, have laws that inhibit greater use of creative financing techniques by universities. This is a very complex and difficult arena. But we do hope to identify such barriers and to formulate proposals for improvements or changes that might be considered by State governments and their public universities.

5. *In the fifth analysis Federal regulations governing the acquisition, management, and use of equipment will be reviewed.*—Recommendations will be made for changes to current regulations that would facilitate equipment acquisition, achieve management improvements and ease burdensome reporting requirements.

6. *The subject of the sixth analysis is future methods of direct Federal investment.*—The current methods or means of Federal funding of research equipment will be evaluated. The benefits and limitations of these methods and the pros and cons of changing them will be assessed. Alternatives will also be explored with an eye to maximizing the return to the Nation of future investment of scarce Federal resources. One option that will be explored is the feasibility of returning to the use of the proven but presently unutilized mechanism of guaranteed loans to rehabilitate university research laboratories and equipment. As the committee knows in 1965 the Higher Education Act established a guaranteed loan program (title VII-C) designed to assist with the rehabilitation of academic laboratories, and that program played a substantial leadership role in mobilizing other State, private and institutional funds. For more than a decade, however, that loan program has not been funded. Reinvestment in the title VII program is one option; others will be considered.

The project contracted with the accounting firm Coopers & Lybrand to do the research and analysis on several of the analyses: Debt financing, tax incentives, Federal and State regulations, and future methods of direct Federal investment. The analysis of opportunities for improvements in university procurement, management, and use of equipment is being carried out by a team of three university people: David Litster, director of MIT's materials science center; Robert Bock, dean of the graduate school at the University of Wisconsin; and Julie Norris, assistant provost of the University of Houston. Over the next four months they will visit and gather information from 12 universities and 8 corporate and Government labs.

Phase II

During the second phase of the project, beginning in the fall of 1984, the results of the six analyses will be disseminated to the university community. Leading higher education associations and science and engineering societies will be invited to join the project as cooperating organizations and to host special seminars, as part of the regularly scheduled meetings of their members.

Regional workshops will be held in September and October 1984. They will be designed to provide opportunities for teams of representatives from universities in each region to share their varying perspectives on the equipment problem. During the workshops each team will be invited to explore the implications for their own institutions of adopting approaches identified by the phase I analyses.

Phase III

The project's final phase will be an agency briefing in Washington to report the results of the project to the sponsoring Federal agencies and to the Congress. A final report will be submitted to the sponsoring agencies in January 1985.

OBSELETE FACILITIES—THE OTHER SIDE OF THE EQUIPMENT PROBLEM

A discussion of the research instrumentation needs of universities is incomplete if it does not also address the interrelated research facilities problem. Modern research instrumentation increasingly requires specialized environments, and many of our research laboratories are obsolete and inadequate settings for modern science. Many require extensive and costly modernization or replacement.

The dimensions of the facilities problem are estimated to be considerable. In 1981 the AAU surveyed the facilities needs of 15 universities, which in fiscal year 1979 accounted for about 22 percent of total Federal obligations for research. The survey was limited to present programs and faculty. It found these institutions able to meet only about half of their projected needs for replacement construction, modernization, repair and renovation and high cost equipment (items capitalized at more than \$100,000). The report's executive summary is attached to this statement. The report has been provided to the staff.

The facilities deficit is almost certainly the most serious long range problem that now confronts our research universities. A recent survey by the University of California, for example, found "staggering" facilities problems, including estimated needs for core academic facilities totaling \$1.6 billion over the next decade. Traditional funding approaches, the university concluded, simply will not meet their need for facilities rehabilitation and replacement. Failure to address this backlog, however, will result in compromised instructional and research programs.

We understand that the National Science Foundation has joined with the Department of Defense and other agencies in preliminary discussions of the need to better understand this problem. We are also encouraged that the problem also has gained the attention of 18 Members of the Senate who have joined as cosponsors of Senate bill 1537, "The University Research Capacity Restoration Act of 1984". This bill, introduced by Senator Danforth and Eagleton, offers a sound blueprint for action by the NSF and five other agencies. It calls on each of these six agencies to invest in the rehabilitation of those university laboratories in which agency research programs are carried out.

Recently the National Commission on Student Financial Assistance (a bipartisan panel created by Pub. L. 96-374, the Education Amendments of 1980) completed its report, "Signs of Trouble and Erosion: A Report on Graduate Education in America". The Commission affirms the seriousness of the instrumentation and facilities deficits and it calls for just such an investment strategy for research instrumentation and facilities rehabilitation as that proposed by S. 1537.

A serious reinvestment strategy is needed. We hope that this committee will consider the facilities problem as part of its continuing deliberations on the research equipment problem and the fiscal year 1985 NSF budget request.

Thank you, Mr. Chairman, for this opportunity to present our views to the committee. I will be pleased to respond to questions.

ATTACHMENT A

PROJECT TO ASSESS AND DISSEMINATE ALTERNATIVE APPROACHES TO MEETING UNIVERSITY RESEARCH EQUIPMENT NEEDS

STEERING COMMITTEE

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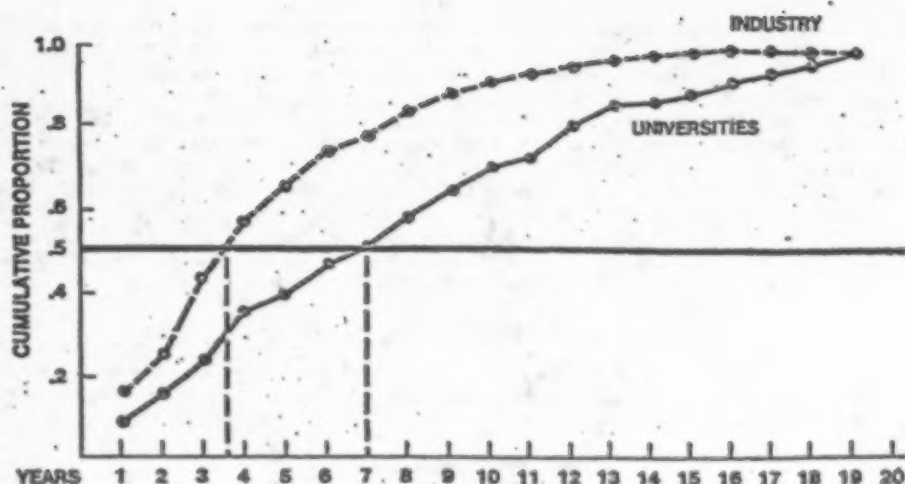
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Age of Instrumentation in Universities Twice That in Industry



ATTACHMENT B

ASSOCIATION OF AMERICAN UNIVERSITIES STATEMENT ON DECISIONMAKING IN FEDERAL FUNDING FOR RESEARCH FACILITIES

The Association of American Universities represents institutions whose faculties are deeply engaged in research. We share with many other institutions and individuals a commitment to advancing the quality of the nation's research effort. Since the vitality of this effort is closely linked to the soundness of decisions made about science by public bodies, it is both appropriate and important for the AAU to state its collective views about the ways in which those decisions are best made.

The United States has evolved an admirable but fragile system of awarding federal funds for research. In general, Congress appropriates funds for the support of broad categories of research. Subsequently, the administering federal agency issues guidelines for making applications in a manner that assures fair and open competition. Researchers then submit detailed proposals that are judged by experts, scientists chosen for their ability to make sound and careful judgments in the scientific area involved. This method maximizes the scientific return on the federal investment by assuring that awards are made on the scientific merit of the proposal and the professional merit of the proposer.

The same method governed most federal programs in support of scientific facilities when such programs existed. However, in the early 1970s, most federal government programs in support of the construction and renovation of research facilities ended. The subsequent decade-long failure to attend to the capital base of university science has led to a backlog of need that has hampered American science and placed great stress on the processes by which the government allocates scientific resources.

We believe that processes based on the informed peer judgments of other scientists need to be preserved and strengthened. We therefore urge scientists, leaders of America's universities, and Members of Congress to support the practice of awarding funds for the support of science on the basis of scientific merit, judged in an objective and informed manner. Further, we urge them to refrain from actions that would make scientific decisions a test of political influence rather than a judgment on the quality of the work to be done. These principles should apply in making decisions about scientific facilities as well as in awarding funds for research projects.

Finally, we urge officials of the national Administration and Members of Congress to deal promptly with the decay of the physical plant that houses much of the nation's basic research. S. 1537, introduced by Senators Danforth and Eagleton, is a bipartisan effort to deal with this national priority and deserves strong and prompt support.

**NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES
STATEMENT ON FEDERAL FUNDING OF ACADEMIC FACILITIES**

In recent years, federal funding of various higher education programs had decreased markedly. In particular, wholly inadequate resources for facilities has led some institutions to seek direct assistance from Congress. The outcome of such a process could be an irrational system of distribution based solely on political influence. In that regard, the National Association of State Universities and Land-Grant Colleges shares the concerns of the Association of American Universities, the National Academy of Sciences, and others, that this approach is unacceptable, in that it could diminish the capability of higher education to carry out its mission in education and research, and we urge Members of Congress and leaders of colleges and universities to refrain from this practice.

We further urge the Congress to fund Title VII of the Higher Education Act and similar programs in other agencies at reasonable levels, and to insure the systematic allocation of resources to satisfy pressing national concerns.

ATTACHMENT C

**THE SCIENTIFIC INSTRUMENTATION NEEDS OF RESEARCH UNIVERSITIES—A REPORT TO
THE NATIONAL SCIENCE FOUNDATION BY THE ASSOCIATION OF AMERICAN UNIVERSITIES, JUNE 1980**

EXECUTIVE SUMMARY

OBJECTIVES OF THE STUDY

Assess the current status of scientific instrumentation in major research universities.

Identify factors which facilitate or impede its development, acquisition, use, and maintenance.

Estimate the future consequences of present funding policies.

Recommend appropriate policy change.

METHODOLOGY

Sixteen universities, six national and government laboratories, and nine commercial laboratories were visited; about 80 department heads and over 250 researchers and research administrators were interviewed in the universities; in addition, the views of approximately 60 researchers and research managers were gathered in visits to national, government, and commercial laboratories.

Five fields of science and engineering were studied: physics, chemistry, biological sciences, earth sciences, and electrical engineering.

Numerical data on instrumentation acquisition, age, and replacement were gathered from 14 universities and four commercial laboratories.

THE PROBLEM

Instrumentation is essential for progress in experimental research. Scientific knowledge has advanced rapidly; new instruments, more costly but qualitatively superior to earlier ones, have allowed measurements previously impossible. The rate of change has been great, competition among researchers intense. The capacity of university researchers to work at the frontiers of knowledge has important consequences for the nation's future research productivity and for the training of future generations of scientists and engineers.

The federal government has adopted a variety of funding policies for the support of research instrumentation: the competitive project system, special instrumentation programs, formula grant programs, block-funded centers, federally sponsored research centers, and regional instrumentation centers chief among them. For about 15 years, federal support for basic research has gradually declined; now support levels are further strained by rapid inflation. But inflationary price increases are simply the rising baseline upon which are superimposed the frequently much larger increases resulting from instrumentation advances.

ASSESSMENT

The great diversity of instrumentation needs found among institutions visited precludes simple generalizations. However, problems in the acquisition, use, and maintenance of research instrumentation were found in all of the leading universities visited. The precise configuration of these needs and problems varies widely. The capabilities of institutions and departments to meet them do also.

University researchers face great difficulty in replacing worn-out or obsolete instrumentation and in acquiring new instruments needed for frontier research. A comparison of university instrumentation inventories with those of two leading commercial laboratories reveals that the median age of university equipment is twice that of the commercial laboratories' instrumentation. Even the nation's major research universities have not kept pace in meeting instrumentation needs. Researchers heavily dependent upon federal funds have witnessed grant size fall behind escalating research requirements. As a result, many work with inadequate tools that impair the pace of research force closure of lines of inquiry, strain operations and maintenance budgets, and compromise the advanced education of graduate students.

Start-up funds for new faculty often are shrinking as costs rise. Support equipment is needed to test, calibrate, and augment primary instruments. Often it is especially difficult to fund. Funding for operation and maintenance cost is increasingly difficult to obtain. As a result, faculty and students sacrifice research time to these routine tasks.

Many research facilities are in need of renovation or replacement; federal funding for these purposes has decreased, however, and universities lack the funds to respond. Signs that aging facilities now impede research were found in many laboratories and support facilities.

Local university needs vary widely, reflecting the unique circumstances under which each institution operates and the great diversity between and even within the five fields studied. Present funding policies do not provide sufficient flexibility to deal with such local circumstances.

When compared with government and commercial laboratories visited, most university laboratories fare poorly. The best-equipped industrial laboratories surpass almost all university laboratories visited. One university researcher captured the sense of disparity and observed, "the ivory towers are now in industry." The director of one leading industrial research laboratory described the struggle of university researchers as he has observed them as "pathetic." When asked to contrast their laboratories with foreign laboratories, a number of university researchers stated that many, most notably those in Japan and West Germany, are now superior.

CONCLUSION

The quality of research instrumentation in major university laboratories has seriously eroded. Not all, but many researchers in the nation's best-funded universities are struggling to work effectively with obsolete tools. The equipment being used in the top ranked universities has a median age twice that of the instrumentation available to leading industrial research laboratories.

Three causes are identified:

A relative decrease in instrumentation support.

Inflexibility within the project system.

Insufficient support for maintenance.

Three major consequences are:

Diminished research productivity.

Reduced training capacity.

Decline in international competitive status.

RECOMMENDATIONS

Federal policy for the support of research instrumentation should provide for a basic three-part funding strategy:

Strengthen instrumentation funding in the project system.

Expand special instrumentation programs.

Create in the National Science Foundation a new, supplemental formula grant program to provide needed flexibility to meet diverse institutional needs.

FUTURE STUDIES

Five studies are recommended: (1) a thorough analysis of foreign research funding policies and programs and their implications for the competitive stature of American science should be undertaken; (2) a study of cooperative research arrangements

between industries and universities and the factors—including federal policies—that encourage and discourage them is needed; (3) the planned assessment of regional instrumentation centers should include consideration of the concerns documented in this report, (4) universities should assess current instrumentation policies and develop mechanisms and incentives designed to promote effective sharing of instrumentation; (5) an assessment of the costs and benefits of federally-mandated equipment inventory and reporting systems should be undertaken.

ATTACHMENT D

THE NATION'S DETERIORATING UNIVERSITY RESEARCH FACILITIES—A SURVEY OF RECENT EXPENDITURES AND PROJECTED NEEDS IN 15 UNIVERSITIES BY THE ASSOCIATION OF AMERICAN UNIVERSITIES, JULY 1981

EXECUTIVE SUMMARY

OBJECTIVES OF THE SURVEY

This survey of 15 leading universities had three objectives:

In the institutions surveyed, document expenditures for research facilities and major (\$100,000 or more) equipment, without regard to source of funds, over the last four years in the following six fields: Biological sciences, Chemical sciences, Earth sciences, Engineering, Physics, Medical schools (10).

Provide responsible estimates, prepared by those universities, of expenditures for research facilities and major equipment that would be required over the next 3 years to meet the research and training needs of only current faculty.

From researchers and department heads, acquire assessments of the major consequences for science, industry, and government if the accumulating facilities needs of their institutions are not addressed.

FINDINGS

In many of the science and engineering departments surveyed, a substantial backlog of research facilities and equipment needs is accumulating. Projected funding needs over the next three years equal almost twice the level of expenditures by universities for their research laboratories and equipment over the past four years. Already, institutions often are unable to provide their basic science and engineering researchers and students with either the modern laboratories or equipment needed to conduct state-of-the-art research and education programs.

The loss of federal contributions to the support of research facilities and the absence of compensatory sources of support has forced many institutions to revivate and repair only those facilities in greatest need. Even this work often is carried out in a necessarily piecemeal fashion which is uneconomical over the long term. Working under such conditions, researchers unavoidably compromise their productivity and future competitiveness.

Relatively few construction projects have been completed in recent years in a majority of the physical sciences and engineering departments surveyed. Many institutions estimate substantial needs for new laboratories, for the expanded modernization and repair of old laboratories and for modern research equipment. Details are provided in the following report and the appendices. The survey's principal findings are the following:

In the last four years, for the six fields surveyed, fifteen leading universities together spent \$400 million from all sources for facilities and major equipment. Half of those expenditures was for a relatively small number of new construction projects; the remaining half, spread over a larger number of generally less costly funding projects, was for facility modernization, major repair and renovation, and special purpose research equipment.

In the next three years, the 15 universities estimate they should spend almost twice as much (\$765 million) just to provide the necessary research facilities and special research equipment for current faculty only. These estimates are in current dollars and, therefore, do not include the added effects of inflation.

New construction to replace outmoded facilities accounts for almost 60 percent of total projected funding requirements across all fields.

In addition, substantial needs for major research equipment were identified in all six fields. These equipment estimates include only major items costing at least \$100,000. As the 1980 AAU report to the National Science Foundation found, most departments also have serious deficiencies of less costly analytical instrumentation and support equipment.

RECOMMENDATIONS

The problems of obsolescence in the nation's university research facilities have been growing for more than a decade. To solve them, a new national investment strategy is needed. That strategy should provide direct, balanced support for university facilities from federal agencies and provide investment incentives designed to involve industry, the states, and the universities in a coordinated effort. The following steps are suggested as starting points:

1. Key Executive agencies should develop a mechanism to periodically assess the condition of university research laboratories and the consequences for the nation of the condition. Such assessments should involve the Office of Science and Technology Policy, the National Science Foundation, the Department of Defense, the Department of Energy, the Department of Health and Human Services, the Department of Agriculture and the National Aeronautics and Space Administration. The views of industry and the universities also should be solicited.

If the initial review corroborates the assessment of this survey the following recommendations should be considered:

2. The facilities and equipment program earlier proposed to be undertaken by the National Science Foundation but deferred should be restored as a priority initiative in Fiscal year 1983.

3. The Department of Defense, Department of Energy, the National Aeronautics and Space Administration, the Department of Health and Human Services, and the Department of Agriculture should establish research instrumentation and facilities rehabilitation programs targeted on the fields of science and engineering of primary significance to their missions. The National Science Foundation should assist in the development, implementation, and coordination of those activities.

4. Incentives should be provided to encourage industries and the states to join with universities and the federal government in renewing the nation's university research laboratories.

5. Interest costs incurred in the construction, modernization, renovation, and repair of facilities in which federally supported research programs are carried out should be allowable indirect costs under OMB Circular A-21

Senator GORTON. Thank you, Doctor.

Dr. Knapp, your outline of the 1985 instrumentation program represents an increase of almost 100 percent when compared to the NSF budget, of 2 years ago. I wonder if you and other members of the panel, for that matter, would comment on what the implications of that change are. Is it because research instrumentation has deteriorated alarmingly, or is it an attempt to keep the lead and be on the cutting edge, or both?

Dr. KNAPP. Mr. Chairman, I think perhaps a little digression to the history of our instrumentation problem would set the stage for the answer to that question. I believe, and I think many others believe that the instrumentation problem at our universities occurred because of the funding pattern that we had in science in this country, particularly with the NSF, but other agencies, too. We had a very rapid increase in funding for science from the 1950's until about 1968, at which time funding in real dollars, constant dollars, leveled off and has stayed constant up until about 2 years ago.

During that time, particularly in the early stages of that abrupt leveling off, people expected funds to be increasing again, as they had in the 10 years previous to that, and deferred instrumentation purchases on research grants, feeling that next year would be a better year, the budgets would be increasing again, and we would then be able to have the instrument in this research, and we could get along for another year without another instrument.

That process went on for more than 10 years, almost 15 years. That led to the alarming statistics which were mentioned by Dr. Zdanis about instrumentation in universities compared to instrumentation in industrial research laboratories. The problem was an

accumulation of 10 to 15 years, not the problem of a year or two or three.

To rectify that, we felt that a many-pronged attack was necessary. It is not just to get back on the cutting edge of science. It is really to get to the ability to do scientific research in a reasonable way, with a great deal of that at the cutting edge, true, but a lot of instrumentation is used for routine sampling and measurements, too.

We decided, in the National Science Foundation, that a multi-pronged effort was necessary. A study of the AAU and others was one of these prongs, to understand other methods of utilizing and financing instrumentation. Within our own organizations, we would let the disciplines decide. Physics is very different from chemistry. It is very different from biology. That leads to some of our instrumentation emphases being in individual grants.

Senator GORTON. While you are on this answer, you have anticipated my next question. You might indicate how it is that you decide on allocations between the different disciplines as well.

Dr. KNAPP. All right. I will try to weave that into this whole answer. In effect, I will go back and start the answer to this particular question with a discussion of that.

We allow the individual disciplines to decide the need and the best response in their own particular problem areas. Chemistry is a discipline, for example, which utilizes a lot of relatively smaller instruments, the \$10,000 variety. Some branches of physics require a multimillion-dollar instrument to do their work. Biology is another small instrument type discipline. The response depends upon the kind of science that is being done, and the need is different in chemistry and in materials science.

In chemistry we have individual grants and regional instrumentation centers which are used to provide instrumentation. In physics, particularly with solid state physics, the MRL's, the centers for research which include instrumentation are a reasonable approach. In high energy physics, we have whole facilities such as the CESR accelerator at Cornell, which is a multimillion-dollar facility. That is the approach we have taken.

This broad-based approach, with the disciplines deciding what they need and allocating their own budgets to rectify that need, is a flexible approach we have been taking over the last 2 years.

Senator GORTON. Will the level that is requested in the budget for this year, if projected out over a number of years, be adequate to meet at least the minimal needs of the field?

Dr. KNAPP. With the other approaches we are taking to funding instrumentation, the 100 percent increase over 1982 budget levels for instrumentation in the Foundation goes a long way to meeting these problems, but it is over a long period of time. It is certainly not in 1 year that we have solved any problems with this level of funding.

Senator GORTON. You have in your budget \$15 million for high technology instrumentation. Would you explain what you mean by this, whether this figure is adequate, and how it differs from other instrumentation purchases.

Dr. KNAPP. The distinction between high technology instrumentation and instrumentation is very difficult to make. The \$15 mil-

lion addition to the budget for high technology instrumentation was an addition of the House Appropriations Committee, I believe. It was not our invention, so to speak. We are very pleased to have that money for instrumentation. We make the distinction on the basis of the type of instrument and the speed with which instrumentation is developing in this particular case. Certain kinds of computers, certain kinds of NMR's, spectrographs, as I mentioned in my testimony, are considered high technology instrumentation.

Senator GORTON. I am sorry I did not allow Drs. Lane and Zdanis to comment. I will pause for a moment now and see if either of them would like to add something to what Dr. Knapp has said.

Dr. ZDANIS. Thank you. I would like to reinforce the comment that Dr. Knapp made that it is a problem of long standing and will not be reversed in the short haul. The difficulty of facing a budgetary cutback in actual dollars for the principal investigator faced with the prospect of having his team dispersed or putting off the purchase of a new instrument for another year, the most common decision is to keep your team together and hope that the NSF will be more generous the following year.

When that happens over a protracted period, it has the consequences that we have seen. It will not be addressed in the short haul. One also needs to distinguish, I think, between two kinds of instruments. The service instrument which can be used by multiple individuals needs to be up and running and serviceable when a principal investigator goes in to make his measurement. It cannot really be used as a research instrument in order to develop the instrumentation. Those instruments are taken apart half the time. They have experimental components in them in order to advance the cutting edge in the field. We need both types that can be used on a daily basis, and we need those people in there to develop the instrumentation that will be the common surface instruments 2, 5, or 10 years from now.

Senator GORTON. Dr. Lane.

Dr. LANE. Yes, Mr. Chairman. I would like to comment that I agree with Dr. Knapp's outline of the history and his description of the nature of the NSF response to the problem. I would like to point out that there has occurred a kind of tragedy in higher education that is not so apparent today, not due, in my view, to any lack of sensitivity on the part of the Federal agencies, but just the history that Dr. Knapp outlined.

Many of our fine universities around the Nation who do not find themselves among the top 20 or 30, but who were quite research active in resource intensive fields like physics and chemistry, have found themselves gradually disappearing from a competitive situation in these fields as the funding available for basic research has steadily gone down in real terms. At the same time, the sophistication in instrumentation necessary to stay in the competitive range in these fields has continued to go up.

I think the hope is that in the future, with the increased recognition of the importance of basic research in these areas, and the vital needs of the young people who are educated everywhere—the best of the young people come from all over the Nation, from many colleges and universities—this situation can be reversed. It is important to recognize that appropriate research activities should be

strengthened in these disciplines, as well as others, in as many universities as possible.

I am certainly not criticizing the Foundation, or necessarily suggesting new programs or new ways of doing business. I simply want to point out what I perceive as a scientist to be a real problem in the country.

Senator GORTON. All of you were here when I asked Dr. Keyworth about the possible alternative of multiuser centers of equipment as a more efficient way to allocate scarce resources. Dr. Knapp and each of the other two of you, I would like your thoughts on that subject. How many such centers do we have? What kind of instrumentation do they have? How can or do we avoid duplication of essentially the same kind of activities?

Dr. KNAPP. I would be pleased to respond to that. It follows directly on the answer I gave before, and Dr. Zdanis has addressed a bit of the problem which you pose in his previous answer. There are individual research grants, regional instrumentation centers, research centers which have a broad range of research, including instrumentation, and then the major facilities that I described.

I believe that the balance that we have between these different types of centers and the supportive instrumentation is about proper. There are some instruments which have to be on research grants. They are not general-purpose instruments. They are very special purpose. They are modified by the researcher. They are not the kind of instruments which a person comes to and does a measurement, goes away, and then looks at his data at another institution. They have to be part of the ongoing research, and we fund those on individual research grants, primarily.

We really do not fund much instrumentation that it is sitting idle and could be used by others. The regional instrumentation center solves the problem of the kind of instrument which you walk up to, make a measurement, and walk away. I think there are 14 of those centers around the country, primarily in chemistry; perhaps some in biology, where this kind of instrumentation is needed. There are 14 MRL's, for research, particularly, in engineering, solid state physics, and materials science.

When we establish our engineering centers—there already are a few and there will be many more—which will be for research and instrumentation in the engineering disciplines, particularly cross-disciplinary centers, where engineering training will be a very important aspect of the work we do.

I think we have a very good balance in the ways we support instrumentation, and I would not suggest any changes. We must be very vigilant that those kinds of instruments which are multiple-user adaptable are used in that way, and the study of the AAU points out ways we can make that better and more efficient.

Dr. ZDANIS. One of the difficulties in looking at the cost comparison between individual instruments and regionalized instruments is that it is really easy to sum the cost of the instruments themselves. It is very much more difficult to ascertain appropriately the cost of a regionalized center and incorporate all of the travel costs that are involved in using it, and incorporate the loss to the home institution of the individual while they are away making the measurement.

These are hidden things which run up the cost of the regionalized centers to a degree which is not apparent when you just look at the raw costs of the instruments themselves.

Senator GORTON. Dr. Zdanis, you talked about John and Jane Doe and the difficulties sometimes of getting gifts from individuals for these purposes. What about industry assistance to universities? Is it widespread in the instrumentation field? Are there barriers which we can overcome so that that cooperation can be greater?

Dr. ZDANIS. The change of the tax laws has helped considerably. It has both increased the awareness of industry of our needs and has provided some incentive for them to participate. There are perhaps limitations there yet in the amount of manufactured components that have to be incorporated in an instrument to qualify the lack of additional software support that could be given along with the instrument that we probably will address in our current study. We would hope to have a better answer for you on that particular issue in a year from now.

With respect to the facilities, though, it is much more difficult to have industry really participate in a meaningful way, especially renovations. It is sometimes possible to have them cooperate in the construction of new quarters. Stanford has been very successful in getting industry to participate, so there is an increased awareness of the issue. But still the renovation issue is one which predominantly falls on the shoulders of the administrators at the institutions.

Senator GORTON. How do we differ in our approach toward new instrumentation, from the approach taken in Japan and West Germany, for example? Dr. Lane, do you want to comment?

Dr. LANE. Mr. Chairman, I was hoping to address the earlier question in regard to supercomputers. Could I digress just a little bit and throw that in?

Senator GORTON. Certainly.

Dr. LANE. Thank you. Then I will also try to respond to the question you just asked.

In the area of computing, industry has, in general, been very helpful directly with the universities. The Foundation has been good at seeking discount arrangements, and the universities have stimulated giving of equipment and so forth.

Sometimes the giving of equipment alone is not the ideal response. A particular piece of equipment may not be what the university needs most often; the university would like a little help with the use and maintenance of the equipment. Universities would really like help with networking, so that some of the nitty-gritty problems around the campus could be solved. I think that is an area where we are seeing improvement.

I am very impressed with industry response. However, if one moves up toward the supercomputer class of equipment, whatever that is for a given generation, then we are talking about multimillion dollar machines and facilities. It seems to me it would be good for the Federal Government to at least look at the possibility of being a little more bold in guaranteeing a portion of the market to industry. If the new computers are developed for a total market that is significantly larger than they now perceive it to be, then those machines which now cost \$4 million or \$5 million might cost

significantly less. It is a marketing decision at this point, and it is possible that everyone could benefit from a change in attitude.

Universities, I think we agree, will play a special role in using advanced computing capability of whatever generation we are talking about in scientific and engineering research and advanced training. That will feed back to industry in exactly the way we hope our system will continue to work.

However, the market right now is so limited for these advanced computer systems that they are terribly expensive. Universities which have purchased them, in many cases have difficulty paying for them. They have to charge rates that I as a researcher have great difficulty paying from my grant or contract. So, I suggest a way in which the Federal Government can get more actively involved is to work a little more closely with universities and industry to attempt to help industry see a different market.

There is no question, I believe, but what hundreds of universities in the Nation, could use supercomputers effectively if they knew well enough in advance that they were going to have them enough in advance so they could properly prepare to make efficient use of this advanced computing capability. We also hope that industry will increasingly provide prototype machines to universities so that the students there can have the advantage of training on machines that will be going into commercial production about the time the students graduate.

Industry then would benefit by having a critical evaluation of their product in actual use; and that kind of synergistic arrangement would certainly be helpful for everyone.

In terms of Japan and Europe, I do not think I am really qualified to answer that. In Japan my feeling is there is much tighter management. Whenever I talk to my colleagues in Japan, I find that the plans have been laid out. There is good long-range planning and cooperation between industry and certainly the universities, the scientists who are involved. So in Japan it seems to be a somewhat more efficient process, one that in many ways is threatening to progress in our own Nation in these areas.

Perhaps you would like to comment on that.

Dr. ZDANIS. I would like to turn to the European side, which I know better, and that is that the support mechanisms for the scientists are superior in Europe to those we see in this country. Technicians for design, construction, insulation of equipment, and especially the maintenance of equipment, is more available in Europe than here, in general.

The maintenance of equipment, which we have not touched on yet this morning, is another outstanding problem that we continue to have. It is one thing to be able to acquire the equipment. It is another thing to be able to house it. It is a third to be able to maintain it in topflight condition.

Senator GORTON. Do any of you disagree with Dr. Keyworth's characterization of the Japanese challenge in supercomputers? In general, do you think that we are behind, or that we are about to be behind, or that we are simply being subjected to some competition which is healthy and which is likely to produce better and faster work here?

Dr. KNAPP. I subscribe to Dr. Keyworth's position. I think we are in a competitive position. We are not behind. However, we could become behind, and these next 5 years are critical to our position in this market, also, our use of these facilities. I think the NSF's response of providing time to universities and to researchers, including graduate students, to use large-scale computing, to learn how they work, to understand how to apply large-scale computing to the particular field that a person represents, to develop a market for our own industry is the proper solution to this problem.

It means putting Federal moneys into the system, and I think they will be moneys very well spent.

Dr. LANE. Certainly I agree with Dr. Knapp's statement in substance. Perhaps I might add that I have a good deal of confidence in the science and engineering capability of our colleagues in Japan. I am very impressed by the scientific work I have seen come out of there. At a recent international conference, certainly the steepness of the slope in scientific response to opportunities is striking in the case of Japan.

In absolute numbers, the papers that were presented in my field were still not comparable with Western Europe or the United States, but the change was dramatic, not just in number, but in the quality of the work as well. Much of that work was done on advanced computers. So I am nervous. I think competition is healthy in science, as I am sure it is in commerce, but I would feel more comfortable if it were possible to make a somewhat bolder response, and to move a little bit faster.

Senator GORTON. You made that very clear in your statement, that you do not feel that \$20 million in this field is enough, that you were having a great deal of difficulty coming up with allocation, for that amount. Perhaps Dr. Knapp and Dr. Zdanis would comment on that, whether or not the \$20 million which is included in this budget is a realistic amount to develop a meaningful super-computer program.

Dr. KNAPP. I would agree with Dr. Keyworth's statement that the problem will be one of an expanding program. The first year's investment of \$20 million gets us started. I am quite pleased we have it in the budget. I believe that, with that money, we will really be able to get going. Dr. Lane is the chairman of the committee looking at this. He could perhaps judge better than I whether or not we could utilize significantly more money in another year.

Senator GORTON. It seems to me he has told us that he could.

Dr. ZDANIS. Independent of the sum of the first year, it seems to me that we know that it would be a continuing program supported by the Foundation and the Congress, so that people can be prepared to accept it, as Dr. Lane has pointed out. One of the difficulties is that there is very little knowledge in a broad-based community on how to use these computers effectively, and so with this kind of a start, and with this assurance that it will be an ongoing program, this first year may be effectively utilized in bringing people up to speed so that a larger sum in future years could be more efficiently used.

Senator GORTON. My understanding is that this year's emphasis is on increasing the access of the academic research community to

this field. What is going to be the focus, Dr. Knapp, of 1985, assuming an authorization and appropriation in the \$20 million range?

Dr. KNAPP. The focus will be the same. Whereas 1984's program is to basically get us started, in 1985 we will expand on all aspects of that program. The provision of time includes several different aspects, the computers themselves, the networking, the local equipment in each university. All of these will require a multiyear effort in order to get to a set of facilities and a network which will allow access by a widely dispersed set of users to as few machines as we have available.

Senator GORTON. Both the NSF Working Group on Computers for Research and the Federal Coordinating Council for Science, Engineering, and Technology have apparently reported that the existing three university supercomputing centers are underutilized. Has the Foundation identified these underutilization difficulties, and examined them in detail, and how does it propose to address the problem in future centers?

Dr. KNAPP. I think Dr. Lane can answer that question, too. I will give you a short answer.

The computer centers at the existing three supercomputing centers on university campuses are underutilized partially because they are underconfigured. That is, there is not as much of the equipment in addition to the computer which is necessary for these to be readily utilized by people who are not already very well trained and cognizant of what it is possible to do with a supercomputer system.

In addition, the utilization of a supercomputer requires a system of people associated with it who can help people who have not used the computer in the past learn the intricacies of programming for such a large device. Usually, in the supercomputer centers at these three universities, this kind of help has not been available. In the centers which were mentioned as being quite successful, the Los Alamos and Livermore centers and the NCAR center, this kind of expert support is available and makes a great deal of difference in how these facilities can be used.

Dr. Lane.

Dr. LANE. I certainly agree with Dr. Knapp's analysis. I would just add a very simple statement. In addition to the configuration not being ideal in some of these institutions, the machine capability and level of staff support not being up to what is needed, these computers are just too expensive. The user of the supercomputer is generally a theorist, and theoretical grants and contracts are not very large. Suppose one individual wants 50 hours of supercomputer time. It is \$100,000 or so, depending upon how much it is subsidized. There simply is not that much money in typical grants and contracts to do this.

There are a couple of options. One is to go abroad. We all have colleagues who do that. I do not know what the numbers are. Another option is to choose a different problem. Now, this may be a very fine problem, one that is worthy of pursuit and that can be done on a small computer, or by analytic techniques. But it still leaves behind a problem that a scientist feels is very important and could be addressed right now, but that requires supercomputing capability. And there the computer sits with idle time. It is too ex-

pensive, to do the problem or at least to do it efficiently and at home. So I think it is primarily the cost.

Senator GORTON. How widespread is that flight to supercomputer centers?

Dr. LANE. I am sorry, Mr. Chairman, I do not have statistical data on that. I do not know if Dr. Knapp does, or perhaps Dr. Zdanis. I know 20 or so colleagues in various fields who have done that.

Senator GORTON. What happens when that takes place? Does that mean that the results of that research are the exclusive property of foreign centers, or is it the joint property of the centers and the American who uses them? Do we still have a significant American scientific and technological gain when our knowledge is used in that fashion?

Dr. LANE. I do not think we have a technological gain in the United States when this happens, at least under some circumstances that I know. Sometimes scientists have a guest appointment with one of the institutes. The research perhaps would be jointly attributable to his or her institution and to the Max Plant institute, for example, but more often he or she goes over on the airplane and all the students and colleagues, are back at home so the university misses a lot.

One misses the collegial interaction, relationship between scientists back on the home campus, and the interaction with students and post-docs. We know there are fields where scarce resources require scientists to travel. High energy physics is a good example. A multibillion dollar machine maybe is the kind of instrument that high energy physicists will feel necessary to do their work in the future. Obviously, in that case there is going to be travel. But computing is not an area where this makes too much sense to most of us in the community. We just have to get busy with networks, using existing technology at first, and then with the planning for future networks so that rapid data transfer can occur, not just across the nation but across the world. However, it is necessary to find and provide access to the kinds of machines that our scientists and engineers need.

So I think there is a loss in having our scientists go abroad in large numbers, but I am sorry, I do not really know what the count is.

Senator GORTON. Do either of you have anything further on those last two questions?

Dr. KNAPP. I think there is a loss, perhaps, in going abroad. However, I think there is a gain, too. I do not have any statistics. I do think that science is an international enterprise and that we should encourage the interchange of science, even if we had all of the supercomputers that we could use in this country and our friends in Western Europe and Japan also had a large number of computers. I think the idea of travel and exchange of research information and research work is very important for science. I would encourage it. I do not think that looking at the number of people who go abroad to do scientific computing is necessarily a statement that it is absolutely impossible to do supercomputing in this country. It partly has to do with who your colleagues are and who are

also working in the same forefront area of a scientific field as you happen to be, as a working scientist.

In this country, at the present time, our scientists and universities do have access to supercomputers. They get that access by teaming on a problem that has NASA, DOE, or NCAR atmospheric science interests. By teaming in that way, they can get access. It would be very difficult for some scientists who want to work on a particular problem which is not in the mission interests of those agencies to get time.

That is what the NSF would like to address with its program, general access to any scientist who has an interesting problem, not necessarily of interest to some of the mission agencies which happen to have large-scale computing facilities.

Senator GORTON. Dr. Knapp, the report by the NSF working group states the need for expanded research to develop advanced numerical computers capable of solving scientific problems beyond the reach of the current generation. The Department of Defense has initiated a program of computers capable of emulating human intelligence. Obviously, the goals of NSF and DOD programs are different, but it seems to me that research in the areas of parallel architectures and component performance is likely to overlap.

What steps has NSF taken to ensure that future research efforts will be coordinated with DOD and, for that matter, other Federal agencies? Or maybe the reverse of that is true. Is there a way in which NSF can benefit from what DOD does?

Dr. KNAPP. We benefit all the time from what DOD, DOE, and NASA do in the supercomputing field. The DARPA, artificial intelligence thrust, is really quite different than the supercomputing thing we are talking about, but they do overlap in some areas. We are quite cognizant of what they are doing. We do this coordination in several different ways. The most direct and formal is the FCCSET Subcommittee on Computing, which meets quite regularly and includes Federal agency representatives from DOE, DOD, NSF, and others.

Informally, the contact is much broader, and particularly the contact that we have by overlapping memberships in advisory committees to the NSF and DOD and DOE. The people on our advisory committee for computing (many of them are advisers to other agencies) bring back and forth with them what is going on, who is doing what in terms of science, in terms of engineering development, and in terms of new equipment development.

Those overlapping memberships get industry and academia, as well as the Federal agencies, involved in this coordination to a very healthy degree. I think it works quite well.

Senator GORTON. Dr. Lane, is this coordination satisfactory?

Dr. LANE. Yes: I agree. Our committee has had only one meeting, but already looking around the table one sees a marvelous collection of minds with the broad expertise and day-to-day contact with the ongoing plans in other agencies. I think the advisory committee mechanism with members who are very much involved in other programs is an extremely good way to coordinate these activities.

On the networking, clearly we are going to pay close attention, for example, to the experience of DOE and their MFE net, their magnetic fusion effort, that has been very successful. That is the

kind of development we will study as we try to do our own planning.

Senator GORTON. Do we have an appropriate balance in the computer research budget between software systems and hardware?

Dr. KNAPP. Let me comment a bit about the software and software development. I think we have a proper balance. The software development is much, more widespread and is very difficult to glean from looking at our budget figures. We have some programs called software development in the computer science development supported by the Foundation, but the kind of support we are talking about for the supercomputers is primarily an effort between computer scientists, physicists, chemists, sociologists, psychologists, whoever is using these facilities.

The kind of software we are talking about is not that kind that is developed in a computer science environment. It is the kind that is developed by someone who has a problem and wants to solve it. So much of theoretical physics, which we fund for example, might be considered software development, because it is working with the development of codes, programs which can be used on computers to solve particular problems.

So it is very difficult to find out what it is we really invest in software development by looking at budget numbers. I think that the support of scientists to use supercomputers with our supercomputer initiative will in fact expand software development dramatically. Even though the provision of time may be from this initiative, a provision of the person's time to develop the software will be under the umbrella of all of the scientific disciplines which use the computers for their own work.

Senator Gorton. Dr. Lane.

Dr. LANE. Yes; I would like to follow up on the example of physics. I completely agree. There are groups today who feel that the appropriate response to difficult theoretical physics problems are specialized architectures. They are in the business of designing various kinds of parallel architectures, but what will go along with that hardware development is a good deal of very advanced software development work by people who are driven by the desire to solve a particularly complex research problem. That development is going to find its way into the computer science community, and there will be a strong interaction along the way.

But let me add, we have had problems in the past. The computer scientists have their business, and the other scientists have theirs, and they are not always close. They are not always trying to solve the same sorts of problems. I think that is one of the important driving forces behind the desire to develop centers, advanced computing centers, or whatever one might wish to call them, to bring together computer scientists, physicists, chemists, psychologists, and others who have similar computational needs, in the same environment so they can work on common computational problems. One set of nonlinear differential equations is much like another. On the other hand, these communities do not interact very effectively in most universities I am aware of. So, the concept of a center with scientists and engineers having access to a sophisticated machine and working closely to try to address similar computational problems that come up in a whole variety of disciplines poses

an exciting possibility. It is something we hope we will be able to make progress on in the future.

Senator GORTON. Dr. Lane, in your testimony, I am pretty certain that you reflected a substantial number of the scientific community in expressing the need for a national computer network to link all of the science and engineering disciplines. I guess I would like to ask Dr. Knapp if NSF has given thought to supporting such a network, and if so, how it would work, and then let both Dr. Zdanis and Dr. Lane comment on your answer.

Dr. KNAPP. Such a network is at the core of our plan. It is what we discussed, the centers, the network, and the local equipment. The network is essential. We feel that there will be no way that all universities who need access to supercomputers will have supercomputers on campus with the facilities that we can afford in the next 4 years.

Senator GORTON. By that you mean that essentially any of these universities or centers could tap into?

Dr. KNAPP. That is correct. We plan, at the present time, to expand the existing network that the NSF has in conjunction with the DOD's network and DOE's network; particularly, though, the network called ARPA-NET, which is a high-speed network, and CS-NET, the net which we have within the Science Foundation. We hope to develop these, in collaboration with the other agencies, develop these into a network which covers all the universities who have the equipment and who have the support to tap into these. It is not terribly expensive to do that. We hope to develop this into a science net which will link computers and scientists at many, many locations around the United States into the few centers we will have in the first few years of this initiative.

Senator GORTON. Do either of the other of you wish to comment?

Dr. ZDANIS. The networking facility is absolutely essential to use the supercomputing capability to the maximum possible extent. It is one of the areas where travel is not necessary, on a continuing basis. When the data goes into a hole in the wall, where it goes is relatively immaterial if the networking capability is there to carry it wherever its location is supposed to be and back again.

However, that is not a complete description of the problem, because just as it is much more meaningful to have a telephone conversation with a colleague that you have met personally and know, it is much easier and in fact essential to have that personal interaction with the computing center before you try to use it remotely. So it is possible after you have had some experience, but absolutely essential in order to keep down the traveltime and the unnecessary time obligations with people who need that kind of computational facility.

Dr. LANE. I would agree. I would say that networking is absolutely, absolutely essential, just to put the third comment on.

The question is, What kind of network? Networking is a research activity, so we are not ready to do everything that any of our colleagues might like to do. The advisory committee at its next meeting is going to address this issue, of how to get started along the lines Dr. Knapp has described, but it is important right now to think about our plans for the necessary research computing activities and other kinds of studies aimed at the future network.

There is a real need to have a network that is friendly to the user, so that one does not have to know how to address every single computer on the network or to get into five different kinds of electronic mail systems in order to communicate. That is not a very good way to proceed. We want an efficient, friendly network that has rapid data capability, so-called broad band, so that you can do color interactive three-dimensional graphics at your desk, a network that in the future I hope, will include video, so that we can communicate in the way we most like to communicate, as we are doing here today.

So we will work very hard on networking. That is an extremely high priority with our committee.

Senator GORTON. I would like to thank all three of you for a very lively and enlightening discussion of these issues.

The committee is adjourned.

[Whereupon, at 11:08 a.m., the subcommittee was adjourned, to reconvene upon the call of the Chair.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

STATEMENT OF AMERICAN PSYCHOLOGICAL ASSOCIATION

The fiscal year 1985 request for the National Science Foundation (NSF) represents a hardship for most of NSF's behavioral and social science research programs despite the fact that limited areas received favorable treatment.

Only large socioeconomic data bases in the social and economic sciences division and instrumentation in the neuroscience program have been proposed for significant increases. We recognize the need for these initiatives and strongly support them. However, these limited increases ignore the need to encourage broader individual investigations that are the backbone of basic research. The study of human behavior extends beyond the collection of demographic information and depends on resources beyond scientific equipment.

Progress in the areas of productivity, education, military preparedness, and in other nationally important issues depends on the human behavior. Understanding the basic human components of these issues so progress can occur is exactly the purpose of NSF's behavioral programs. Scientists working on different aspects of human motivation, learning, and training is what is required. Yet, the 1985 NSF budget proposal allows for almost none of this.

In the Administration's proposal, NSF as a whole is slated for a 12.4 percent increase over the fiscal year 1984 budget. For the Research and Related Activities portion of the NSF budget, an increase of 14.6 percent has been proposed. These requests are strong signals that basic research is seen as an important activity even in a time of fiscal turbulence and constraint. Yet, to give just one example, the cognitive science program at NSF is targeted for only a 5.2 percent increase. Given past budget reductions, this amounts to fewer real dollars than were available in this area in 1980. Even more alarming are the proposals of only 3.8 percent for social and developmental psychology, 4.7 percent for psychobiology, 7 percent for sensory physiology and perception, and 4.1 percent for linguistics. The budget request claims that the increases in these areas would result in "increased attention to such important research areas as human origins, the learning process, and studies in the development cognitive capacities including language." It is difficult to expect this budget to sustain increased attention in these areas since the proposals described above are simply token gestures that do nothing to offset the cuts made in earlier budgets.

We believe that there are at least two ways to ameliorate the picture that the fiscal year 1985 budget for NSF presents for many behavioral and social sciences. One is that any increase Congress targets for NSF should in part be distributed to create a more equitable base of support across all of the behavioral and social science research programs at NSF. An alternative, given the likelihood that Congress will resist increasing budgets this year, is to redistribute the funds within the NSF budget to enhance the behavioral and social science programs. We believe this could be accomplished without affecting the administration's objectives regarding instrumentation and maintaining data banks.

An additional concern is that the Administration has not renewed the \$5 million set-aside for teaching and learning research that was appropriated by Congress in fiscal year 1984. Three million of this set-aside is being administered by the cognitive and developmental programs at NSF. These funds are being used to support high-quality research projects in such areas as mathematical thinking in children or how children come to understand the concepts of Physics. We believe this research program is an important element in improving the quality of science education in this nation and we are concerned that the momentum of this effort will be greatly diminished without continued support from NSF.

In order to realize the potential of behavioral and social science research for improving the human condition and increasing scientific knowledge, there must be a more consistent and equitable basis of support for the NSF programs in these areas. We urge Congress to reject the notion that there is hierarchy among the sciences

and instead, to place the funding for NSF's behavioral and social science programs on more stable ground than they have experienced in the past several years.

STATEMENT OF ANNA J. HARRISON, PRESIDENT, AMERICAN ASSOCIATION FOR THE
ADVANCEMENT OF SCIENCE

I am Anna Harrison, president of the American Association for the Advancement of Science. First, a few words about AAAS. AAAS has a membership of approximately 135 thousand. This encompasses a wide array of individuals professionally involved in the investigation of physical, biological, behavioral, social, political and economic phenomena and the use of physical, biological, behavioral, social, political and economic phenomena to solve problems and resolve issues.

The unique potential of AAAS is its capacity to facilitate communication among the great multiplicity of scientific, engineering and related professional societies, to provide mechanisms to address issues of concern to these organizations and to provide public forums to address issues which involve the relation of science, engineering and technology to society. The activities of AAAS reflect its strong commitment to the use of science, engineering and technology to enhance the quality of life of this and succeeding generations.

We have a vital interest in the level and the rate of growth of federal support for investigations in mathematics, science and engineering and for education in mathematics, science and engineering at all levels.

The \$1.5 billion proposed fiscal year 1985 NSF budget is very reassuring. In a period of alarming national deficits, this 14 percent increase over the \$1.3 billion of the fiscal year 1984 current plan demonstrates the commitment of the current administration to the support of mathematics, science and engineering research through the National Science Foundation. The overall increase in NSF's R&D budget is again one of the largest R&D increases among the federal agencies.

To assess the NSF budget, from the standpoint of AAAS, requires an inspection of both the magnitude and the rate of growth of proposed obligations by activity and subactivity. The attached table is essentially the budget summary table given on page 32 in the green booklet, National Science Foundation Budget Summary Fiscal Year 1985, with one column deleted and two columns added. The column deleted is the incremental difference between fiscal year 1984 current plan and the fiscal year 1985 proposed budget. The added columns are fiscal year 1980 (actual) and the percent changes from fiscal year 1980 to fiscal year 1985 corrected for inflation. There have been a few corrections of minor magnitudes in some of the figures in the NSF Budget Summary fiscal year 1985 table as published in the green booklet.

My focus for the moment will be upon the first four directorates. These four directorates account for \$1.2 billion of the fiscal year 1985 budget and I shall refer to these directorates as the four R&D directorates. Two other directorates will be considered separately.

The fiscal year 1985 proposed budget for each of the four R&D directorates has a very significant increase compared to the fiscal year 1984 current plan, ranging from 12.6 percent for Biological, Behavioral and Social Science to 21.6 percent for Engineering. All subactivities within the four directorates show significant real growth, ranging from 8.2 percent to 24.3 percent in current dollars. The pattern of increases for fiscal year 1985 is very similar to that for fiscal year 1984, although slightly less in magnitude.

An inspection of the subactivities of these four R&D directorates indicate that three of the four deal primarily, but not exclusively, with investigations in mathematics, investigations of physical phenomena, and investigations in the use of mathematics and physical phenomena, in solving problems. These three directorates are: Mathematical and Physical Sciences, Engineering; and Astronomical, Atmospheric, Earth and Ocean Sciences, with a total proposed budget of \$0.994 billion. NSF supported investigations of biological, behavioral, social, political and economic phenomena, and the use of biological, behavioral, social, political and economic phenomena in solving problems and resolving issues are primarily, but not entirely, grouped together in the fourth directorate, Biological, Behavioral, and Social Sciences with a proposed budget of \$0.25 billion.

A somewhat different pattern of growth emerges if the proposed fiscal year 1985 budget is compared with the fiscal year 1980 (actual) budget. By directorates, the percent changes from fiscal year 1980 to fiscal year 1985 (corrected for inflation) range from a decrease of 1.2 percent for Biological, Behavioral and Social Sciences to an increase of 39.2 percent for Engineering. By subactivity, percent changes range from a decrease of 48.7 percent for Social and Economic Sciences to an in-

crease of 71.5 percent for Electrical, Computer and Systems Engineering. For the five-year period, the funding of two other subactivities also decreased. The decreases are 2.2 percent for Behavioral and Neural Sciences and 14.2 percent for Information Science and Technology.

I raise the question of the adequacy of the national investment in the investigation of biological, behavioral, social, political and economic phenomena and the investigation of the use of biological, behavioral, social, political and economic phenomena in solving problems and resolving issues. This is a very fundamental question. The answer is a value judgment and can only be made for the nation by the public through the surrogates of the public—those elected by the public and those appointed by those elected.

To explore the question involves a consideration of the ways scientific and engineering investigations serve the public good. Science, the investigation of phenomena, generates a body of scientific knowledge consisting of a data base, an array of methodologies and an array of concepts. Engineering, the investigation of how to solve problems, generates a body of engineering knowledge consisting of a data base, an array of methodologies and an array of concepts. The combined body of knowledge serves society in at least three significant ways.

(1) It enhances our capacities to carry on further investigations of phenomena and further investigations of how to solve problems.

(2) It is in part the basis of our perception of our physical, biological, social, political and economic environment, in part the basis of our perception of ourselves and our relations with others and in part the basis of our perception of our capabilities to carry on further investigations and to solve problems. And,

(3) It fosters technological innovation, supports technology (the production and delivery of goods and services) and supports the effective use of the products of technology.

Approximately three quarters of the proposed fiscal year 1985 budget for the four R&D directorates is for the support of investigations in mathematics, investigations of physical phenomena and investigations of how to solve problems (engineering) using physical phenomena.

The scientific, engineering and technological community cannot solve societal issues. Only society can solve societal issues. Scientists and engineers can identify issues, assess the nature and magnitude of the issues, identify areas requiring further investigations, propose technological options, assess the probable positive impacts and the probable negative impacts of each option (including the option to do nothing) on society. Societal issues have to do with the quality of life and decisions having to do with the quality of life are prerogative of the public and the surrogates of the public. Once the decision is made to implement a particular option, scientists and engineers have a great deal to do with the implementation of that option.

I consider the selective use of technology to enhance the quality of life of this and succeeding generations to be one of one most significant societal issues. Concerns related to the quality of life include national defense and national economic growth but are in no sense limited to those two very significant issues.

Every technological change, brought about by either transfer or innovation, has a negative impact on society regardless of how great the positive impact of that technological change upon society. There is no direct proof for this statement. For some years I have challenged audiences to cite examples of technological change for which the statement is not true. I still know of no example for which it is not true. The subset of society that derives the benefits may not be the subset that bears the burdens. The timeframe within which the benefits become evident may be quite different from the timeframe within which the burdens become evident. The nature and magnitude of the benefits may be quite different from the nature and the magnitude of the burdens. The goal is, of course, to selectively use technology to enhance the quality of life and more equably disperse the benefits and burdens of technological change.

We have yet to develop generally accepted quality of life indicators and the practice of using economic indicators is at best a very inadequate substitute—particularly if the data base cannot be disaggregated to monitor identifiable subsets of society in successive time intervals.

The sweet/bitter consequence of technological change is not a unique characteristic of technological change. It is instead a characteristic of change—all social, political and economic change. The goal of technological transfer and technological innovation is change.

Traditionally, engineering has been the investigation of problem solving through the utilization of physical phenomena. The subactivities of the NSF fiscal year 1985 budget of the Engineering Directorate encompass this type of engineering. Today,

engineering also encompasses the investigation of problems solving utilizing biological phenomena and terms such as bioengineering and genetic engineering have become a part of our language.

Parallel approaches to the solution of problems and the resolution of societal issues involve and utilize behavioral, social, political and economic phenomena. Societal issues such as abused children are only very remotely related to physical phenomena and the resolution of such issues is not to be found in the utilization of physical phenomena. Even the resolution of issues, such as waste disposal, which do involve physical, chemical and biological phenomena are dependent upon the resolution of a host of behavioral, social, economic and political problems as well as the development of technological options involving physical and biological phenomena. The approach to the resolution of international conflict through negotiation is highly dependent upon the knowledge and understanding of the social, economic and political structures and priorities of the nations involved and an understanding of the relation of proposed solutions to those structures and priorities.

To assess the adequacy of the federal support for basic research in the biological, behavioral and social sciences goes far beyond a consideration of the NSF budget. Under the proposed fiscal year 1985 budget, NSF would support less than 17 percent of the total federal basic research effort. We are all familiar with the support of investigation of biological phenomena in departments such as Agriculture and Health and Human Services. Other sources of support for investigations of behavioral, social, political and economic phenomena are not as visible.

I am a physical chemist and am well aware of and very proud of our Nation's tremendous capabilities to investigate physical phenomena, to use physical phenomena to develop technological options and to use the data base, the methodologies and the concepts of the physical sciences and of engineering to investigate biological phenomena and to investigate extremely large and complex systems such as the oceans. The capacity of this Nation to plan and undoubtedly build and effectively use the long base line array of radio telescopes is an elegant display of past accomplishments and current capabilities. It is exactly this pride in the past and this confidence in our current capabilities that leads me to be so concerned that limited knowledge and understanding of behavioral, social, political and economic phenomena could inhibit the resolution of societal issues and the enhancement of the quality of life.

The AAAS Board recognizes the synergistic nature of science and engineering and also the growing unity of science and engineering, even though the disciplines of science and the disciplines of engineering are rapidly proliferating. The AAAS Board is in the process of taking to the AAAS Council a recommendation for a change in AAAS goals to recognize and facilitate the growing unity of science and engineering and the AAAS would support the investigation of mechanisms to bring science and engineering closer together in federal agencies.

The Scientific, Technological and International Directorate (STIA) is quite different in structure and foundation from the four R&D directorates. One of its more interesting features is that it coordinates a number of activities which are carried out by the R&D directorates and funded through the R&D directorates in the proposed fiscal year 1985 budget to the extent of \$80.7 million. These special activities include the NSF Small Business Innovation Research Program, the Indo-US Science and Technology Initiative, Research Opportunities for Women, Presidential Young Investigators Research Awards and Support for Predominantly Undergraduate Institutions. This approach assures the standards of excellence and processes of peer review characteristic of NSF R&D directorates. It is too early to assess the success of this approach. In principle, I find the approach attractive and suspect that the degree of success will be closely related to the quality of oversight within STIA and also the level of oversight of the NSF Director. It may require diligence to assure that these activities do not become diffused and possibly distorted or diverted by the R&D directorates.

Another subactivity of STIA is policy research and analysis. I believe that this should involve two types of research and I am not confident that it does. The two types of research are: (1) research on science policy as a discipline and (2) research and analysis as a basis of formulating agency or government policies dealing with science, technology and natural resources. Both types of research and analysis are important but they are different. I believe that it is important to recognize and maintain the difference. In the first case, the investigator is a student of science policy and presumably has no vested interest in the outcome of the analysis. In the second case, the investigator becomes a participant in the formation of policy dealing with science, technology and natural resources and may impose personal value judgment on the outcome of the analysis. There is ample evidence of research of the

second kind. It is not clear how much support is given to investigations of the first type—the research essential to the development of the discipline of science policy. The first type of research parallels the type of research essential to the development of the discipline of chemistry.

STIA also has the responsibility to conduct surveys and maintain the science resource data base. AAAS places a high value on the potential usefulness of this data base for research, including research to assess the entry of women, minorities and the physically handicapped into scientific and engineering careers and the movement of women, minorities and the physically handicapped up the career ladders of scientific and engineering professions. We recommend oversight to insure that the data base for scientific and engineering personnel can be disaggregated to yield this information.

The fiscal year 1985 budget for the Science and Engineering Education Directorate is stated in terms of two subactivities, Graduate Research Fellowships and Precollege Science and Mathematics Education.

A modest increase in funding for fellowships provides for a modest increase in the number of fellowships and in the stipends of the fellowships. This well-established program remains intact.

The proposed fiscal year 1985 budget is 22 percent lower than the funds made available under the fiscal year 1984 current plan for precollege science and mathematics education.

I find this action to be absolutely astounding. Even assuming that Congress will intervene and increase the funding for precollege education, the Science and Engineering Education Directorate will have been denied the opportunity to design and to present a coherent program. The course taken by the Directorate seems to be the presentation of a very nebulous array of programs that far exceeds the level of funding made available in the proposed budget. There will undoubtedly be proposals and some meritorious proposals will be funded, but there will be no identifiable thrust by the National Science Foundation. We need leadership from the National Science Foundation in precollege education and in my opinion, we do not have it.

I serve on the Education Commission of the States Task Force on Education for Economic Growth and am well aware of the initiatives being taken in many of the states largely as a consequence of the leadership of the governors of those states. The progress being made is impressive. These initiatives for the most part address the environment within which education takes place—the number of required courses, pay for teachers, the availability of equipment, the length of the school day, the length of the school year, discipline, etc. They do not tend to address the nature of the educational experience itself. To address the nature of the educational experience in mathematics and science for all students at the precollege level is, to me, uniquely appropriate to the National Science Foundation. In the smorgasbord of programs to the National Science Foundation. In the smorgasbord of programs mentioned in the supporting budget documents, there are opportunities to address the nature of the educational experience but there is no thrust. The value of the whole should exceed the value of the sum of the parts.

One characteristic of young people is that they grow up to be the adults who do the work of the world and make the value judgments that determine the direction and rate of the expansion of scientific and engineering knowledge, the direction and rate of expansion of technological capabilities and the use of those technological capabilities.

The remainder of this statement will consist of brief comments on a variety of general issues.

INTERNATIONAL ACTIVITIES

AAAS interests, goals and practices are entirely consistent with the National Science Board Statement on Science in the International Setting (September 1982) and it is not necessary to restate those principles here. (A copy of the Board statement is attached.) We urge a stable rate of growth in the support of programs consistent with the NSB statement. One of the AAAS activities is to serve as the secretariat for the Consortium of AAAS Affiliated Scientific Societies for International Programs. The Consortium provides a communication system for about 70 scientific and engineering societies with international programs.

ACCESS TO COMPUTER FACILITIES AND ELECTRONIC INFORMATION SYSTEMS

AAAS recognizes the essential nature of ready access to appropriate computer facilities and to scientific and engineering information for all scientists and engineers in all scientific and engineering disciplines and we urge NSF to assist scien-

tists and engineers to discover the potential of computer methodologies appropriate to their research and to facilitate access to computer facilities and information systems through networking and siting appropriate computers at strategic locations. In particular, we make the plea that scientists and engineers, in subdisciplines that have yet to embrace wholeheartedly computer methodologies, be involved in the strategic planning for the installation of computers and the development of networks.

We recognize that computer generations follow computer generations and that only long-term planning can insure the availability of the latest generation of computer systems. Access and utilization to these to advanced computers and information systems is revolutionizing the ways in which scientific and engineering investigations are carried out. This is an issue that goes far beyond the capabilities of any one agency to address in an adequate fashion for the nation. It calls for strategic thinking in terms of what are appropriate national actions—governmental and private—and how the support shall be provided.

ADMINISTRATIVE ISSUES

Personal comments

The scientific and engineering community was shaken by the circumstances under which some of the assistant directors at NSF were asked to leave in late 1982. At the time, I was assured that I would be reassured when the identity of the replacements became known. The sad fact is that five of the directorates discussed in this statement are still operating under the leadership of acting assistant directors. Equally troubling is that several of these acting assistant directors continue to fulfill as well the responsibilities of positions they held before the appointment to an acting assistant director. This is not reassuring to the scientific and engineering community.

Second comment

During the last years that I served on the National Science Board, I chaired the Program Committee of the Board. On the basis of that experience, I strongly support the recommendation of the Chairman of the National Science Board to amend the NSF Act to allow the Board to delegate the Director approved authority for grants that do not exceed \$6 million in total or \$1.5 million in any one year. Even in 1977 and 1978 the current maxima of \$2 and \$0.5 million excessively impossible to develop an in depth concept of the activities of NSF in the support of small science.

THE NSF BUDGET PROCESS

Personal comment

I regret the pattern of events that pits a commitment to science and engineering education against a commitment to research in science and engineering. Many of us discover that we have met the enemy and it is us. We are committed to both. This conflict is accentuated by the frequently reoccurring pattern of a very low proposed budget for science and engineering education being raised by Congress without increasing the total NSF budget. The net result is "that funds are transferred from research to education." I understand the game that is being played but I wonder if those who play it understand how divisive it is to the scientific and engineering community. Research and education are synergistic and they should be perceived to be synergistic.

GENERAL COMMENT

Personal commitment

The NSF fiscal year 1985 proposed budget is a strong budget and any criticisms that I have made and questions that I have raised are derived from my confidence that NSF is a vital foundation and that it is fully capable of providing an even higher level of leadership and service to the scientific and engineering community and to the Nation as a whole.

TABLE—R&D IN THE NATIONAL SCIENCE FOUNDATION

[Dollars in millions]

	Fiscal year 1980 actual	Fiscal year 1983 actual	Fiscal year 1984 current plan	Fiscal year 1985 budget	Percent change, fiscal year 1984-85	Fiscal year 1980-85 constant dollars (percent)
Mathematical and physical sciences:						
Mathematical sciences.....	\$25.0	\$34.8	\$41.5	\$50.5	+21.7	+46.4
Computer research.....	18.4	29.3	33.9	39.3	+15.9	+55.3
Physics.....	63.4	89.2	105.9	121.8	+15.0	+39.2
Chemistry.....	51.5	67.6	80.0	92.1	+15.1	+29.8
Materials research.....	68.7	81.1	97.5	115.0	+15.9	+19.2
International awards.....		-1.5				
Total.....	227.0	300.5	358.8	416.7	+16.1	+33.0
Engineering:						
Electrical, computer, and systems engineering.....	18.9	29.5	36.0	44.7	+24.2	+71.5
Chemical and process engineering.....	16.0	22.6	26.6	32.5	+22.2	+47.1
Civil and environmental engineering.....	27.9	30.5	33.8	39.8	+17.8	+3.5
Mechanical engineering and applied mechanics.....	13.8	19.4	24.3	30.1	+23.9	+59.6
International awards.....		-0.9				
Total.....	76.6	101.1	120.7	147.1	+21.9	+39.2
Biological, behavioral, and social sciences:						
Physiology, cellular, and molecular biology.....	72.1	87.3	102.1	116.4	+14.0	+17.3
Biotic systems and resources.....	36.8	46.0	53.4	59.9	+12.2	+17.8
Behavioral and neural sciences.....	31.4	34.0	38.5	42.2	+9.6	-2.8
Social and economic sciences.....	39.7	20.3	24.6	28.0	+13.8	-48.7
Information science and technology.....	5.6	5.5	6.1	6.6	+8.2	-14.2
International awards.....		-1.9				
Total.....	185.7	191.2	224.7	253.1	+12.6	-1.2
Astronomical, Atmospheric, Earth, and Ocean Sciences:						
Astronomical sciences.....	56.7	62.7	78.2	93.4	+19.4	+19.5
Atmospheric sciences.....	63.3	75.5	89.3	98.6	+10.4	+12.8
Earth sciences.....	26.0	34.9	41.5	48.6	+17.1	+36.0
Ocean sciences.....	66.3	102.5	113.7	124.9	+9.9	+36.7
Arctic research program.....	5.8	6.2	7.4	8.0	+8.1	+7
International awards.....		-1.0				
Total.....	218.1	280.8	330.1	373.3	+13.1	+24.2
Scientific, Technological, and international affairs:						
Industrial science and technological innovation.....	10.4	14.5	17.6	23.4	+33.0	+63.1
International cooperative scientific activities.....	13.7	4.6	5.5	5.5	0.0	-70.8
Policy research and analysis.....	5.5	4.3	4.6	4.7	+2.2	
Science resources studies.....	2.7	3.6	4.2	4.3	+2.4	
Research initiation and improvement.....	12.9	11.8	8.9	9.0	+1.1	
International awards.....		+5.3				
All other programs.....	7.0					
Total.....	52.2	44.1	40.8	46.9	+15.0	-34.8
Science and engineering education:						
Graduate.....			20.3	21.0	+3.4	
Precollege.....			68.6	54.7	-20.2	
Total.....			88.9	75.7	-14.8	

STATEMENT ON SCIENCE IN THE INTERNATIONAL SETTING AS ADOPTED BY THE
NATIONAL SCIENCE BOARD AT ITS 238TH MEETING ON SEPTEMBER 16-17, 1982

The United States is at a critical point in its international scientific relationships: American scientists no longer lead in every field of science and U.S. industry is significantly challenged in many areas of technology.

The global nature of many scientific problems, the resolution of which may significantly influence the future well-being of U.S. society, requires increased international cooperation and a coherent approach for successful study.

The increased scale and complexity of many modern scientific projects requires facilities and operations whose costs strongly suggest the utility of international coordination, sharing and, in some cases, cooperative funding.

Foreign policy considerations play an increasingly important role in the conduct of international scientific activities.

Science and technology are becoming increasingly interdependent, and the national security implications of technology transfer have led to increased discussion of the need for additional controls on the international scientific communication process itself.

In view of the importance of these issues and their potential impact on the overall health of U.S. science, the National Science Board has addressed the broad topic of "Science in the International Setting." This statement expresses the Board's present policy and consolidates and extends a number of past Board actions on this subject.

IMPORTANCE OF INTERNATIONAL SCIENTIFIC COOPERATION

Scientific interaction at the international level is an essential element in the continued vitality of science. Historically, the Nation has profited greatly from its positive stance of encouraging outstanding scientists from throughout the world to be aware of and participate in our scientific activities and encouraging U.S. scientists to travel and interact closely with scientific projects in other nations.

There are certain fields in which international cooperation and access are essential to the effective conduct of research because the scientific questions being addressed are inherently global in nature. Examples include research related to climatology, oceanography, space applications, health, population and resource studies, acid rain, carbon dioxide buildup and heating of the atmosphere. Many of these issues are of serious concern to the future well-being of our citizens, as well as to those of other nations. Many disciplines, such as plant sciences, anthropology, and the geophysical sciences, require access to scientific sites in foreign areas.

The cost, scale and complexity of scientific facilities in many disciplines, such as high energy physics and astronomy, provide strong incentives for nations to share in the planning, financing, and use of such facilities.

The value of international scientific cooperation is by no means limited to the use of large facilities. Individual scientists in specialized fields often find international collaborative efforts to be of signal importance in facilitating the advancement of their fields.

SCIENTIFIC COOPERATION WITH VARIOUS NATIONS

The objective of maintaining the vigor of the U.S. research effort requires a broad, world-wide program of cooperation with outstanding scientists in many nations.

Cooperation with the industrialized democracies, such as OECD members and our NATO allies, is clearly of great value to the economic well-being and industrial capability of our own Nation as well as theirs. These nations enjoy comparable levels of technical sophistication and the potential for sharing advanced, costly facilities. Since opportunities for interaction with these countries are readily available, the greatest latitude should be given to individual cooperation and exchanges independent of formal bilateral programs. However, the NSF should continue to participate in selected intergovernmental agreements that serve identifiable useful functions.

Developing countries, many of which have a corps of highly qualified scientists, also offer significant opportunities for scientific cooperation, including unique possibilities for access to scientifically important territories and environments. Moreover, international scientific cooperation may offer economic, diplomatic and other policy benefits going beyond the immediate needs and interests of science per se. With many of these countries, bilateral agreements, including the provision for support and maintenance of continuity, are required to ensure the success of collaborative scientific activities. Since direct contact between the involved scientists is essential to ensure the effectiveness of the programs, the U.S. should continue to encourage an emphasis in its bilateral agreement on such scientist-to-scientist cooperation.

There is also evidence of benefit for U.S. science from contacts with scientists from Communist countries. Opportunities for individual scientific cooperation, even in the presence of strained political relationships, keep open channels for communication and can lay foundations for enhanced cooperation should conditions become more propitious in the future. Exchanges with Communist countries should be conducted so that commensurate benefits flow to both sides.

The levels of scientific activity with these three classes of nations will vary in time as scientific opportunities change and in reflection of the evolution of our foreign relations. At any given time, these levels will reflect a balance between needs and opportunities for American science and the goals and requirements of foreign policy and national security.

The Board concludes that because the international dimension is intrinsic to the nature of scientific research and because of the Foundation's role in the support of the Nation's foreign policy, the Director of the Foundation must play a significant role, in collaboration with the Department of State and the Executive Office of the President, in the development and implementation of the international science policy of the United States.

The Board strongly supports the Director in that very important dimension of his responsibilities. So that the Board can take these policy considerations fully into account in its planning, the Board must keep abreast of international initiatives and U.S. foreign policy objectives that should be considered in formulating the Foundation's priorities and budget.

MODALITIES FOR FACILITATING INTERNATIONAL SCIENTIFIC COOPERATION

Agencies such as the NSF, as well as universities and nongovernmental professional scientific organizations, will each have unique and important contributions to make toward the success of cooperative international scientific activities. The Foundation, by virtue of its fundamental and broad-based scientific program, should take the initiative, in cooperation with the Department of State and other agencies as appropriate, to bring together potential international partners to accomplish the necessary planning and implementation for international sharing or collaboration in fundamental science and engineering research.

Under the auspices of the International Council of Scientific Unions, a number of multilateral scientific programs have been successfully carried out, often with the cooperation and assistance of intergovernmental organizations and member governments. The International Geophysical Year program (the 25th anniversary of which is being commemorated now) has offered a useful paradigm for subsequent efforts in the atmospheric geophysical and ocean regimes. The Foundation should use such multilateral channels when attractive opportunities arise.

The role of the National Academy of Sciences (NAS, NAE, IOM) as a Congressionally chartered, yet private organization, has enabled it to relate to many nongovernmental institutions throughout the United States in cooperating with other countries. This is a source of strength of which the Foundation should take full advantage. The National Academy has an especially significant role to play in facilitating international scientific cooperation, both by virtue of serving as the U.S. representative in connection with various nongovernmental international scientific organizations, and through bonds of cooperation with similar academies in other countries.

INTERNATIONAL SCIENTIFIC COMMUNICATION

Maintenance of a strong technological position is central to our national security and to our economic and commercial vitality. Technology leadership depends on a creative and vigorous science engineering base which, in turn, benefits greatly from an effective international exchange of scientific and engineering information. Opportunities for exchange of novel ideas and rapid assimilation of new research results provided by contacts and conferences have long been important to the progress of science. These exchanges have served the Nation well in terms of contributing to rapid advances in basic research, innovation, application of research results, and development of state-of-the-art technology.

Foreign students, teachers, and researchers working on American campuses are also an important resource, both for our universities and ultimately for our industry's success in foreign markets. As a result of the advanced state of development of the U.S. scientific enterprise, the U.S. has been particularly efficient in absorbing, understanding, and extending new ideas from all sources, foreign and domestic; and this in itself is becoming an increasing vital component of the success of U.S. science and its contributions to technology and industrial strength.

Advances in scientific knowledge are usually incremental and interdependent. They are facilitated by knowledge of other scientists' successes and failures, and by the criticism of one's peers—that is, by open discussion. Openness on the campuses of American colleges and universities is particularly central; for it is there that new research directions are frequently conceived, and there that the next generation of scientists is trained. Restrictions which diminish that openness are likely to have serious costs to science and, ultimately, to national security. Such costs should be carefully considered in all dimensions before implementing any actions that would compromise the traditional open environment that has served us so well in the past.

In those special instances where universities choose to undertake proprietary or classified work, they may have to accept constraints on communication.

CONCLUDING STATEMENT

The nature of science requires that its international dimension be considered an organic aspect of the scientific enterprise. This dimension must be actively provided for in all Foundation programs, from education and fellowships to the various disciplinary efforts in the natural sciences, social sciences, and engineering. Planning for new facilities and the setting of priorities for major scientific investigations and programs should be carried out with the full recognition of the priorities of other countries and in an environment which encourages complementarity or planned supplementation, cost sharing, and coherence of the various efforts of cooperating countries. National Science Foundation organization and management procedures should reflect these principles.

The Board will continue its analysis of the subject of "Science in the International Setting" in connection with the preparation of the Sixteenth Board Report of this same title.

STATEMENT OF DR. ROBERT D. KERSTEN, P.E., DEAN OF THE COLLEGE OF ENGINEERING, UNIVERSITY OF CENTRAL FLORIDA

Chairman Gorton and members of the Subcommittee: I am pleased to respond to your invitation to discuss institutional arrangements for engineering education and research and share some views on the fiscal year 1985 budget request for the National Science Foundation. While the views expressed here are my own, I have the very strong support and concurrence of the Engineering Education Task Force consisting of: Dr. Robert D. Kersten (University of Central Florida), Chairman, representing the National Society of Professional Engineers; Dr. Robert H. Page (Texas A&M University) representing the Engineering Deans Council of ASEE; Dr. W. Edward Lear (Executive Director of ASEE) representing the American Society for Engineering Education; Dr. Donald D. Glower (Ohio State University) representing the National Association of State Universities and Land Grant Colleges.

Collectively, our membership consists of over 100,000 individual engineers from all disciplines and employment areas, over 100 corporate employers of engineers, and about 400 colleges and universities which enroll nearly one-half million engineering students in the United States.

Our task force was formed last spring in response to a request from the Engineering Deans Council, the organization of the nation's engineering school deans. We were asked to develop a long-term legislative solution to engineering education and research problems which could be embraced by the diverse community represented by the group. Early on in our meeting, it was concluded that before we addressed the specific problems of faculty shortages, equipment deficiencies, and under investment in engineering research, we needed to focus on institutional arrangements to support innovation and research.

This decision was based on one major concern. It is clear that efforts are being made to address specific engineering education problems by the Administration, the National Academy of Engineering, and especially by this Subcommittee. Programs such as the Manufacturing Technology Centers proposed in S. 1286 and the Cross-disciplinary Centers proposed in the FY '85 NSF budget are important steps in the right direction. We applaud these initiatives, but believe they are being developed without proper analysis of the agency that is expected to carry them out. We believe their potency and effectiveness will be inhibited by the limitations of the National Science Foundation. We therefore decided to direct our attention toward these structural shortcomings.

SUMMARY

Before I go into detail on this, I would like to summarize my thoughts for the Subcommittee.

(1) Innovation depends on a strong and continuous link between science and engineering. In fact, the boundary between science and engineering research in the innovation process is not a distinct one. It is desirable to keep science and engineering closely linked in the Federal support structure.

(2) While some people include engineering research in the rubric of "basic" research, we believe the term "fundamental engineering research" is more appropriate. There is a common perception that science is basic research, and clearly within the Federal domain, while most other research is applied, and therefore the responsibility of the private sector. This dichotomy is, of course, inaccurate. It leaves fundamental engineering research in limbo, without a clear Federal role. This research generates future technology from scientific knowledge, through investigation of systems, manufacturing processes, materials and methods. It is different that basic scientific research, yet not applied or commercial in orientation. Fundamental engineering research is academically-based, non-proprietary, and generic in nature.

(3) The National Science Foundation is currently giving some emphasis to engineering, but without the benefit of a clear mandate to do so. NSF support for engineering has, through the years, been sporadic and at times questionable. This stems largely from the fact that NSF has no clearly stated engineering role in its mission statement. We need to institutionalize engineering within the Foundation, and make it clear that we are committed to producing a strong science and engineering base in order to compete more effectively in world markets.

(4) We would like to call your attention to a bill recently introduced in the House by your colleagues, Mr. Brown and Mr. Skeen. Their bill, HR 4822, embraces these concerns in a most appropriate manner, and has our full support. H.R. 4822 would amend the NSF mission statement by extending the authorized functions to include fundamental engineering research and education, change the name to the National Science and Engineering Foundation, and make other modifications in the governance structure to reflect the Foundation's emphasis on both science and engineering. Mr. Brown and Mr. Skeen are to be applauded for their outstanding leadership on this issue.

ENGINEERING AND INTERNATIONAL COMPETITION

We share the Subcommittee's interest in achieving the most appropriate institutional arrangements to support innovation and research. Such support should contribute to improved productivity and real economic growth and, in short, an improved competitive posture for American industry.

Whatever research we choose to do will not be of world-class, competitive quality unless we are able to assure the flow of the highest quality technical talent throughout the innovation process. This process will bring increased benefits to our nation only if all of the partners (i.e., government, industry, and universities) are able to conduct their affairs from positions of strength and excellence.

Our engineering schools are clearly not operating from a position of strength. As the Business-Higher Education Forum recently reported to President Reagan, "Unless the clear inadequacy of the U.S. engineering manpower and education systems is rectified, it jeopardizes the future competitiveness of our nation's technologically based industries and defense."

We know you are well aware of the problems, so will not go into detail here. However, the following facts will be helpful to keep in mind:

Over the last decade, engineering student enrollments have skyrocketed 115 percent, while the parallel faculty growth has been a mere 12 percent.

The cost of modernizing engineering laboratories is estimated at \$1.2 billion, at 1971 enrollment levels. Corrected to 1981 enrollment figures, estimated cost increases to \$2.2 billion. This does not even include computing equipment.

Our major international competitors are producing more engineers than we do. Japan alone educates six times as many engineers per capita than the U.S.

Engineering accounts for only 7 percent of the total undergraduate degrees produced annually in the U.S., compared to 21 percent in Japan, 35 percent in the Soviet Union, and 37 percent in West Germany.

Competent economic authorities have concluded that from about one-third to one-half of all the growth in the American economy in the past 100 years has come from technological change. The fact that in the last decade there has been an apparent decline in the rate of technological change is of great concern.

We realize that there are many factors (e.g., international trade policy, economic conditions, capital formation, changing energy relationships, etc.) contributing to these problems which may be beyond the scope of these hearings. Independent of these other factors, however, continued technological competitiveness will depend on the quality of our technical talent and ability to innovate. Without an adequate supply of qualified engineering talent, our strong science base will have a limited impact on our nation's economic well-being.

FEDERAL ROLE IN INNOVATION

Innovation cannot be forced; it can be fostered, encourage, or excited. Innovation implies a qualitative change as when some new technology is tried for the first time. This is typically done to improve economic efficiency of a process, to make a superior product, or improve one's competitive position. It may imply a new "system," provide for more efficient utilization of resources, or creation of new products. Innovation therefore involves a significant technological and economic risk and certain front-end costs. We suggest that the successful innovation process involves four major steps—

- (a) basic scientific research;
- (b) fundamental engineering research;
- (c) applied research and development; and
- (d) commercialization or product development.

One way or another, entrepreneurs, industrial groups, and mission-oriented agencies have carried on (c) and (d), which is entirely appropriate given the proprietary nature of this work. At the same time, the nation's universities, supported in part by the National Science Foundation, are responsible for a significant portion of (a). But fundamental engineering research, (b), which is the link from (a) to (c) and (d), is a weak bridge, without a firm foundation of support either in industry or government.

A Federal role in "basic" scientific research is clearly appropriate. A Federal role in "applied R&D" is commonly accepted in the mission-oriented agencies and the private sector. We concur that there should be a major Federal role in "commercialization." On the other hand, we believe there should be a major Federal role in the area of "fundamental engineering research," which leverages non-Federal participation to the maximum extent possible.

The similarities between science and engineering research are many. The scientific method is applicable to both science research and engineering research. The terms basic and applied research are difficult to define. The same work done by a scientist and engineer may be classified as basic by the former and applied by the latter. Pure research is often used by some as a further subdivision of basic research. To distinguish between science and engineering by separating these functions in different Federal structures would further weaken this synergistic relationship.

Fundamental engineering research is vital to the national welfare and security. Without a definite focus on a specific application, most industries only sparingly support long-range fundamental engineering research. The results of fundamental research are a part of the national wealth upon which all can draw for future use, and should be a function of the National Science Foundation.

The Vannevar Bush report "Science, the Endless Frontier" delivered to President Truman in July, 1945, envisioned a National Research Foundation to execute a program, largely by way of grants to educational institutions, for the conduct of basic research deemed important to the national defense and welfare.

What we obtained in 1950 was the National Science Foundation, whose mission became "basic scientific research." The Foundation has been uniquely successful in fostering scientific progress, and should continue to do so. Yet it has not devoted enough attention to the "general research needs" as envisioned by Dr. Bush. In today's terms, these needs include fundamental engineering research, which is the primary agent in the development of new technology from scientific information. For example, scientific research resulted in the identification of electrostatically charged particles, and then defined their behavior. Engineering research led to the design of systems which took advantage of that scientific information to develop modern photocopying processes.

The major undertakings in the World War II era (e.g., electronics, nuclear energy, radar, computers, etc.) were more engineering than science. Doctoral level engineering personnel were almost non-existent, the National Academy of Engineering had not been founded, and so quite naturally the perceived need was science.

SCIENCE AND ENGINEERING PARTNERSHIP

We believe that engineering has come of age, academically and professionally and should be recognized as a mature partner in the innovation process. NSF has concentrated almost exclusively on "basic scientific research" for nearly 34 years. As our nation's growth has become increasingly based on technological progress, our dependence on quality engineering research and talent is greater than ever. Attempts to enhance the role of engineering within NSF have been limited to date, due in part to the restrictions imposed by the current mission statement. The interplay of science and engineering, which is crucial to the advancement of both and to the development of new technology, should not be hampered by institutional barriers.

In the U.S. nearly all major universities have strong science departments, as well as strong engineering departments. Thus the U.S. academic structure provides a rationale for expanding NSF activities in engineering rather than assigning the support of engineering research and education to some other new or existing agency. NSF has done a very good job in "basic scientific research" and we believe can and will perform equally well in fundamental engineering areas.

CURRENT TRENDS

We are aware of recent initiatives by NSF to encourage a greater emphasis on engineering research and education. We can only applaud every such step, but it has taken a decade of benign neglect to focus attention on the problem.

The NSF budget request for fiscal year 1985 is \$1.5 billion, an increase of 13.6 percent over fiscal year 1984. The increase in all research and related activities in all areas other than engineering totals \$140.1 million, which is approximately equal to the absolute value of engineering research across all the various disciplines. Further, it is proposed that the Engineering Directorate be increased to a level of \$147.1 million or 21.8 percent over fiscal year 1984. The percentage increase for engineering appears impressive when applied to so small a base. However, in fiscal year 1984, engineering was 9.1 percent of the NSF total. With the proposed increase for fiscal year 1985, it will become 9.8 percent of the NSF total. This apparent growth curve is encouraging. Both the direction and volume are appropriate. We suggest, however, that structural changes within the Foundation are necessary to best accommodate this emerging emphasis.

The reactivation of the Science and Engineering Education Directorate is another significant, positive step. It should be noted that two-thirds of the proposed budget is dedicated to pre-college mathematics and science education. The balance will support 550 new and 1,000 continuing NSF Graduate Fellows in all areas of science and engineering. Recent studies by ASEE identified a need for 1,200 Fellows annually in engineering alone, in order to address the shortage of engineering faculty.

The Presidential Young Investigator Research Awards is an outstanding program. However, 100 awards per year to all areas of science and 100 awards per year to all areas of engineering is inadequate. An AAES study recommended support to 500 new assistant professor-level engineering faculty each year for four years.

Efforts to improve research grant awards and other program activities in order to insure improvements in laboratory instrumentation are to be commended. However, no funds are designated for improvements in instructional laboratories, which is where the most critical deficiencies in equipment lie.

Similarly, while efforts are being initiated to address needs in "advanced scientific computing," no movement is detected in bringing undergraduate engineer instruction up to the state-of-the art in use of computing technology.

CONCLUSION

Our conclusion is that these current trends, however positive, do not go far enough and may not be permanent. There is a need for assured attention to engineering problems over time. There is nothing in NSF's mission statement or name which identifies fundamental engineering research and education as a priority for Foundation support. Instead, as the legislative history of the enabling legislation states: "Support for applied research . . . is made permissive and at the discretion of the Foundation . . . Nevertheless, there are important occasions when Foundation backing for applied research appears warranted . . . Such research is either inseparable from or is intertwined with basic research, or is a logical extension of the basic research already being supported. This type of applied research is, of course, normal for schools of engineering."

While we in no way believe support for engineering should detract from or be supported at the expense of basic science, we do believe that a stronger commitment to engineering is appropriate to the Foundation's mission statement. Foundation backing for fundamental engineering research is warranted on more than "important occasions"; it is essential to our nation's future health and technological leadership. We cannot afford to have this commitment based on executive decisions, vulnerable to political tides. The National Science Foundation should provide the institutional framework to support engineering, and thus innovation, within the Federal structure. A legislative mandate would certainly enhance the ability of NSF to meet this objective.

Mr. Chairman, I would like to thank you and all your colleagues for raising this important topic. This Subcommittee has made tremendous contributions to our nation's science and technology policy over the years. I would be pleased to answer any questions, and offer you the full cooperation and assistance of our Task Force as your work progresses.

STATEMENT OF DR. ROBERTA BALSTAD MILLER, EXECUTIVE DIRECTOR, CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS

My name is Roberta Balstad Miller. I am the Executive Director of the Consortium of Social Science Associations (COSSA), an umbrella organization that represents 175,000 social and behavioral scientists across the social science disciplines. A list of COSSA Members, Affiliates, and Contributors is attached to my testimony.

COSSA is pleased that the National Science Foundation will receive a budget increase of 13.6 percent for fiscal year 1985. Despite the severe constraints on the fiscal year 1985 budget imposed by the size of the federal deficit, it is important to maintain the nation's investment in basic research. Without such continuing investment, the United States would become steadily less able to compete with other nations economically, the quality of our science and inventiveness of our technology would decline, and we would weaken the flexibility of our economy in the future.

The Director of the Foundation, Dr. Edward Knapp, has discussed NSF plans for advancing the state-of-the-art in scientific computing facilities. Among the research areas he singled out for mention was the need of the social sciences for computers. I would like to underscore that need. Social science data sets are exceedingly complex. They require sophisticated computing equipment that can handle large bodies of data and complicated multivariate modeling and econometric procedures.

I will turn now to the question of budget levels for NSF research programs in the social and behavioral sciences. Members of this Subcommittee do not need to be reminded of the major cuts in NSF budgets for the social and behavioral sciences in fiscal year 1981 and fiscal year 1982.

In fiscal year 1985, the budgets of the social and behavioral science research programs in the Directorate for Biological, Behavioral, and Social Sciences (BBS) are scheduled for an overall budget increase of 10 percent, principally for support of the large scale data bases. This is an important and necessary emphasis. These data bases have suffered from the budget cuts over the past several years. They are expensive, yet they cannot be postponed until budgets are increased again. If a survey—such as the National Election Study (NES), or the General Social Survey (GSS)—cannot be conducted at the required time, its scientific value is impaired. The fiscal year 1985 funding provided for the social and behavioral science programs in the BBS budget will relieve some of the funding pressures on these data bases.

Despite the proposed 10 percent increase in fiscal year 1985 for the social and behavioral sciences as a whole, they will still be funded at a level that is 10 percent below their fiscal year 1980 level—even without taking inflation into account. If we calculate the effects of inflation, the proposed level for fiscal year 1985 is 31 percent lower than the fiscal year 1980 level. The share of NSF spending devoted to the social and behavioral science programs falls from 5.9 percent to 3.3 percent between 1980 and 1982 and will rise under the administration's request only to 3.6 percent, a drop of 40 percent in the share of the social and behavioral sciences in NSF spending. Two charts with these and other NSF budget figures are attached to my testimony, and I request that they be printed in the hearing record.

We face a situation in which the social and behavioral sciences are now receiving budget increases that would be adequate had outlays not been slashed so deeply in 1981 and 1982. But those cuts did occur and should not be allowed to stand.

The consequences of these cuts are most apparent in the decline of single investigator projects, the seed-bed of social science research and training. The effects of this false economy are predictable and pernicious. Proposals are whittled down and

stretched out to spread available funding, thereby causing delays in research and reductions in training. Scientifically ambitious investigations are jettisoned for less ambitious projects that can be accomplished less expensively. A strong research system requires not only the development and maintenance of good data bases, but also the support of established scholars and training for their successors. The support that is provided this year for the large scale data bases is a step in the right direction. An important next step is to increase support for individual investigator projects.

We realize that Congress must scrutinize every appropriation this year to see if the nation can afford it. In answer to that question, we urge you to look at developments in basic research in the social and behavioral sciences. This is what the National Academy of Sciences/National Research Council did recently. The report of that investigation, entitled Behavioral and Social Science Research: A National Resource, describes and strongly endorses the scientific advances that have taken place in the social and behavioral sciences in recent years.

Another way to consider the question of increased support for social and behavioral science research at NSF is to examine some of the problems we face as a nation and the research that is conducted by social and behavioral scientists.

For example, we face a slow-down in productivity growth. Social and behavioral scientists conduct research on worker productivity and management efficiency. Social science experiments on worker productivity and quality control have led to effective techniques for linking participative decision-making and the acceptance of innovations in the workplace.

We are deregulating many branches of the economy. Hundreds of billions of dollars of investment and tens of millions of jobs are involved. Surely the investment of a few million dollars in the study of the effects of this monumental social and economic experiment is only prudent.

Newspapers report on the lag in performance of U.S. students in science and mathematics relative to students in other countries. Can we afford to curtail social and behavioral science research on memory and cognition, teaching and learning?

We face continuing problems in the courts and in the marketplace with the issue of whether wage differences between men and women are based on sex or on experience, skills, performance, or other factors. Do we wish to make decisions in these areas bereft of data and research that would enable us to compare individuals with similar experience and training and sort out the various influences on income?

The basic research in all these and many other areas has been supported by NSF in the past and we respectfully suggest that additional work is needed now.

We recognize the budget problems created for the Congress by the size of the federal deficit. However, we think that on policy grounds and on substantive grounds, the Subcommittee should establish the goal of returning the social and behavioral science programs in the National Science Foundation to their fiscal year 1980 levels in constant dollars. We realize that this may take time, but feel strongly that the goal must be set.

If, therefore, the Subcommittee increases the authorization level for NSF's Research and Related Activities, we ask that the increase be earmarked for social and behavioral science research. If, on the other hand, the Subcommittee decides it cannot increase the NSF research budget this year, we ask that it include in the authorization report a strong recommendation that the Foundation restore the social and behavioral science programs to their fiscal year 1980 level in fiscal year 1986 dollars next year.

NATIONAL SCIENCE FOUNDATION FUNDING FOR SELECTED DIRECTORATES AND PROGRAMS

[In million of dollars]

	Actual fiscal year 1980	Actual fiscal year 1981	Actual fiscal year 1982	Actual fiscal year 1983	Actual fiscal year 1984	Proposed fiscal year 1985	Percent change fiscal year 1984-85	Percent change fiscal year 1980-85
Director for Mathematical and Physical Sciences (MPS).....	227.0	256.5	272.9	299.7	359.5	416.7	+16	+84
Director for Astronomic/Atmospheric Earth and Ocean Sciences (AAEO).....	218.1	236.3	240.0	276.2	330.3	373.3	+13	+71
Director for Engineering (ENG).....	76.6	83.8	93.3	101.1	120.7	147.1	+22	+92
Director for Scientific, Technological and International Affairs (STIA).....	36.6	36.0	40.3	44.1	40.8	48.9	+15	+28
Director for Biological, Behavioral, and Social Sciences (BBS).....	185.7	185.6	176.0	190.2	224.8	253.1	+13	+36
Social and Behavioral Science Programs in BBS.....	52.4	43.7	32.3	36.0	42.8	47.2	+10	-10
Social and Behavioral Science as Proportion of Research and Related Activities (percent).....	5.9	4.6	3.3	3.7	3.8	3.6	.....	.....
Science and Engineering Education.....	77.2	64.7	20.9	16.1	88.9	75.7	15	-2

NATIONAL SCIENCE FOUNDATION SOCIAL AND BEHAVIORAL SCIENCE RESEARCH PROGRAMS IN BBS

[In millions of dollars]

	Actual fiscal year 1980	Actual fiscal year 1981	Actual fiscal year 1982	Actual fiscal year 1983	Actual fiscal year 1984	Proposed fiscal year 1985	Percent change fiscal year 1984-85	Percent change fiscal year 1980-85
Division of Behavioral and Neural Sciences (selected programs)								
Neuroscience:								
Psychobiology.....	4.5	4.3	3.4	3.7	4.2	4.4	+5	2
Cognitive Science:								
Memory and Cognitive Process.....	2.6	2.4	2.2	2.3	2.6	2.8	+8	+8
Social and Dev. Psychology.....	3.3	2.6	1.5	2.1	2.6	2.7	+4	18
(Applied Psychology—absorbed elsewhere).....	1.4	1.1	.....	.....	.....	.....	.....	.....
Linguistics.....	2.7	2.2	2.1	2.2	2.4	2.5	+4	7
Anthropology.....	6.6	6.0	5.5	5.8	6.4	6.8	+6	+3
.....								
Subtotal.....	21.1	18.6	14.7	16.1	18.2	19.2	+5	9
Division of Social and Economic Science:								

Division of Social and Economic Science:

Economics and Geography:									
Economics.....	12.2	9.4	6.3	7.1	9.4	10.25	+9	16	
Geography.....	1.6	1.2	0.7	0.8	1.0	1.3	+30	-19	
Social Measurement and Analysis:									
Sociology.....	3.9	3.0	2.2	2.4	2.95	3.65	+24	6	
Meas. Meth./Data Resources.....	5.0	3.9	2.9	3.3	3.6	3.4	6	32	
History/Philosophy of Science.....	1.5	1.1	0.9	1.1	1.35	1.6	+19	+7	
Political and Policy Sciences:									
Political Science.....	3.6	2.9	2.1	2.3	2.8	3.6	+29	.....	
Law and Social Sciences.....	0.9	0.9	1.1	1.2	1.4	1.7	+21	+89	
Regulation and Policy Analysis.....	2.6	2.7	0.9	0.9	1.1	1.3	+18	50	
Decision and Management Science.....	.....	.....	0.5	0.8	1.0	1.2	+20	N/A	
Subtotal.....	31.3	25.1	17.6	19.9	24.6	28.0	+14	11	
Total, Social and Behavioral Science Research Programs.....									
	52.4	43.7	32.3	36.0	42.8	47.2	+10	10	

¹ In fiscal year 1981, this program was combined with the law and policy program of the Division of Applied Research.

STATEMENT OF THE NATIONAL INSTITUTE FOR ENTREPRENEURIAL TECHNOLOGY

GREATER NSF SUPPORT FOR UNIVERSITY/INDUSTRY PROGRAMS NEEDED

A thriving system of scientific and engineering research and educational institutions, when encouraged to interface with industry, provides a vital part of the infrastructure needed for economic growth. University/industry linkages play a major role in stimulating rapid transitions from fundamental scientific and engineering research to practical implementations of innovations. Encouraging the formation of such linkages must be a vital element of Federal Government efforts to stimulate a renaissance of our industrial competitiveness on world markets. The National Science Foundation (NSF) has played, and can continue to play, a role in facilitating these linkages through direct and indirect funding programs.

It is widely recognized that corporate return-on-investment calculations will undervalue the benefits derived from basic and applied research. No individual firm can capture all of these benefits for itself. Investment levels which may be rational for individual companies, however, are not necessarily rational for the country. The challenges presented by Japanese and European technology on world markets highlight the importance of stimulating new partnerships between the elements of our national science and technology system.

The NSF Industry/University Cooperative Research Centers and Cooperative Research Projects programs, in the Division of Industrial Science and Technology (ISTI), are excellent examples of how direct funding programs can stimulate linkages. These programs are leveraging private-sector funding for basic and advanced research. This benefits American companies which require knowledge and highly educated employees to develop new products and manufacturing processes. It benefits universities by providing new sources of capital for researchers and students. At the same time the inclusion of program evaluations as on-going components of program management, have contributed greatly to our knowledge of the innovation process and to more effective Federal Government roles in that process.

Without Federal seed money, this synergism would likely not have occurred. Increased funding should be provided to expand ISTI programs so that they may fine-tune their existing operations on the basis of program evaluations and explore alternative models for encouraging industry/university linkages.

NSF can also stimulate better university-industry relations through its Small Business Innovation Research (SBIR) Program. This program, the model for Pub. L. 97-219, is making a major contribution to the formation and growth of our country's high-technology industries.

We urge the Committee to increase the funding for ISTI by \$3.15 million, \$1 million each for Industry/University Cooperative Research Centers Program, and Productivity Improvement Research. These funds should be used to explore new models and to fund projects and centers designed to speed the transition from academia to commercialization in supercomputers and biotechnology and to conduct additional research on problems of innovation in automated manufacturing and on the implementation of technological innovations in general. An additional \$150,000 should be provided for handling the increased administrative burden that has resulted from proposal pressure on the SBIR program. In addition, we urge report language which would direct NSF to explore partial early payment and other means of enabling start-up firms with limited cash flow to participate in the program.

Direct funding programs alone are not sufficient. The development of thriving high-technology businesses around Palo Alto and Boston indicate the importance of the presence of major science and engineering research universities for the information and growth of high-technology companies. Survey research sponsored by Congress, Federal agencies, and organizations such as the National Institute for Entrepreneurial Technology repeatedly confirm the importance of the presence of major universities for the formation and growth of high-technology firms. Adequate funding for university science and engineering research and education is a second mechanism for stimulating consulting, internship, licensing, and other university/industry linkages.

Federal funds account for over 66 percent of all academic R&D and are by far the largest source of R&D funds for almost all academic institutions. Unfortunately, Federal R&D funding for universities is excessively concentrated. As a recent NSF-funded study by Edward Malecki points out, the top 100 academic institutional recipients of Federal R&D funds account for over 82 percent of total funds going to such institutions. Yet these institutions are located in only 36 states (including the District of Columbia) with 62 of the top 100 in 12 states. Indeed 10 states received over 56 percent of Federal R&D obligations for universities.

Such concentration is unfortunate. It inhibits the development of national centers of scientific and engineering research and education in all parts of the United States. Concentration means that technological creativity and innovation is inhibited by the lack of an adequate research and education infrastructure for these activities.

The solution to cocentration is not to withdraw funding from existing national centers. Rather, additional funds should be made available to support research and education in order that existing state and regional universities may be upgraded into national centers. Such funding should be provided in a manner which encourages linkages between universities and firms of all sizes.

We urge the Committee to support the NSF request for Centers for Cross-Disciplinary Research in Engineering. We also request that the Committee include language in its report urging NSF to model funding for these Centers on the approach developed by the Industry/University Cooperative Research Centers in order to endure such centers strive for financial self-sufficiency.

A thriving system of universities—linked to small, medium, and large companies—is issential for long-term economic growth. The spirit of inquiry and innovation that such a system creates is a national resource.

STATEMENT OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

The American Society of Civil Engineers (ASCE), founded in 1852, is the oldest national engineering society in the United States. Membership, held by individual professional engineers rather than companies or organizations, is over 95,000. The membership is about equally divided among consulting engineers or those who work for them; engineers working for federal, state or local governments, and those employed in research, industry, construction or in universities. The Society's major goals are to develop engineers who will improve technology and apply it to further the objectives of society as a whole, to promote the dedication and technical capability of its members and to advance the professional and economic stature of civil engineers.

The Administration's budget proposal for fiscal year 1985 once again calls for the elimination of the Center for Building Technology (CBT) and the Center for Fire Research (CFR) of the National Bureau of Standards (NBS). The rationale is that these programs are more properly the role of the private sector and state and local governments. Frankly, the Society is surprised and disturbed that the Administration is once again trying to zero out these programs. Last year, after the fiscal 1984 budget proposed to eliminate this funding, numerous statements were filed on behalf of a variety of different organizations which stressed the valuable role performed by the Center for Building Technology and the Center for Fire Research. As we did last year, ASCE wishes to go on record as strongly supporting the Center for Building Technology and the Center for Fire Research and opposing the Administration plan for eliminating their budgets in fiscal 1985. The specialized laboratory facilities and equipment and the comprehensive abilities of the professional staffs of the Center for Building Technology and Center for Fire Research constitute public resources which should be more fully tapped and not arbitrarily diminished by short-sighted budgetary concerns.

The Center for Building Technology, which performs field, laboratory and analytical research to develop measurement techniques and to evaluate the properties of buildings, construction materials, components and systems, cannot be replaced by proprietary research programs. As civil engineers, the members of the Society need sound technical information to make responsible and cost effective decisions in the building process. The Center for Building Technology provides such information in a way that no private organization can. Neither the Society nor other non-profit organizations can replace the technical abilities and professional expertise of the CBT. The private sector would be unable and unwilling to fill the major void created by eliminating the Center for Building Technology.

In addition to being the principal source for the necessary information which allows the development of voluntary building standards, the Center for Building Technology research provides other benefits which far outweigh its costs. Perhaps the most important of these is that it establishes the technical information which allows policy makers to reduce the burdens of unnecessary or ineffective regulations while assuring that the safety of the public is preserved. The CBT has also served as the natural laboratory investigating major building and construction failures, identifying the technical causes and publishing the result to educate the public and the building industry. This Subcommittee should also recognize that without a specific

budget authorization, the CBT would be incapable of providing the authoritative laboratory support for federal agencies which need assistance in developing criteria for the design, construction and maintenance of their facilities. Although we cannot offer a financial analysis, it is likely that the technical support from the CBT provides the federal government with savings in the life-cycle costs of its buildings which annually exceed the budget authorizations for the Center. To not provide a specific level of new funding for the CBT would be to ignore a productive investment opportunity.

The Center for Fire Research also contributes to public safety in a way that no privately funded research effort could. The research and evaluation work of the CFR is illustrative of a cost-effective basic capability which should be promoted by the federal government. The termination of this important life-safety fire research essentially would stop the development of fire control technology in the United States. If the specter of eliminating life-saving opportunities does not deter efforts to zero-fund the CFR, the cost-saving opportunities should persuade a budget-conscious government to reconsider the proposal. Fire-safe building design techniques can save money for all sectors of our society. Without the CFR, fundamental research programs will stop and engineering criteria will not longer be generated. Such a short-sighted budget approach is deleterious to the economic interests of the American people and threatens all our lives.

From the perspective of the professional expertise of civil engineers, the prospect of eliminating the Center for Building Technology and Center for Fire Research is tragic. We suggest that specific authorizations for each Center, at a minimum of the fiscal 1984 levels, are called for and urge the Subcommittee to allow the Centers' vital work to continue.

CHILDREN'S TELEVISION WORKSHOP,
New York, N.Y., February 17, 1984.

MR. CHAIRMAN: I am writing regarding the authorization of major support for the National Science Foundation and its educational programs. The Children's Television Workshop is a non-profit organization which produces "Sesame Street", "The Electric Company", and "3-2-1 Contact."

In recent years we have received support from the National Science Foundation for the development and production of two production cycles, totaling 100 programs, of "3-2-1 Contact"—a series that presents science information in variety of formats to young people in the 8-12 year old age group. We are currently at work on plans for a 3rd series of "3-2-1 Contact" programs to provide a growing sequence of entertaining science education for this important age group of children.

The problems of not enough students electing to pursue higher education in science and math do not spring full-blown at the high school or college level. They start at the elementary grades, where teachers are least prepared to teach science, and where states are least rigorous in setting standards for science curriculum and for certification of science teachers.

Although the level of factual knowledge is a problem, even more basic is the attitudinal problem, the need to get kids "turned on" to science—the critical target age range for doing this is eight to twelve. This is the goal and the target audience of "3-2-1 Contact", a national effort in place that deals successfully with the problem for this age range.

With major funding from the National Science Foundation, the Department of Education, and the Corporation for Public Broadcasting, we recently completed the production of a second season of "3-2-1 Contact" programs. We reached 16.3 million households—youngsters and their parents—with these programs during October and November of 1983, more than would be reached by any other means with this educational information.

"3-2-1 Contact" is widely used in classrooms as well. We offer free teachers guides and teacher training workshops in how to use the programs. Over a four-year period, "3-2-1 Contact" outreach staff conducted 520 workshops, directly reaching over 70,000 teachers and other youth serving leaders, and distributed over 650,000 teachers' guides. This kind of effort is a valuable extra tool for teachers to have available, and our efforts in this area should be continued and expanded.

Other NSF funds have gone into the development of "The Brain", a new educational series for adults produced by WNET, New York, to be seen on public TV this fall. And the outstanding sciences series, "Nova", produced by WGBH-TV, Boston, began several years ago as a result of vital help from NSF.

Opportunities for using TV for science education abound. Tens of thousands of adults and young people are even taking courses in computer methods by watching

TV during lunch or other periods at their places of work. More than 75,000 adults are taking credit courses from their local public TV stations via the Public Broadcasting Service's Adult Learning Service. By using these techniques for teacher training, for example, many times more teachers can be reached through the media than could attend many years of campus summer institutes.

For two years after the completion of the first season, we unsuccessfully sought renewal of corporate funding for "3-2-1 Contact's" second season. As a result, the reduced funding meant that we could not do a complete series of 65 programs, but only 40. Thus the federal government stands as the only dependable funding source related directly to science and technology.

Our success with the television leads us to urge that the authorization for NSF explicitly encourage the use of tested, cost-effective mass media technologies to meet the enormous challenge for increased science education given to NSF by the Congress and the nation. We urge that you not only authorize but encourage NSF to provide leadership in the uses of media and technology for education purposes in the whole range of NSF education activities, and that sufficient funds be authorized to allow for their full development. The public will be well served by the continuing support of NSF and of the Congress in these vital areas of science education.

Cordially yours,

JOAN GANZ COONEY, *President.*

SNOCO, INC.
Carrollton, Tex., March 9, 1984.

HON. SLADE GORTON,
Chairman, Science Technology Space Subcommittee, Commerce, Science, and Transportation, Washington, D.C.

DEAR SENATOR GORTON: The FTP division of our company is concerned with digital technology and is involved in providing useful technical information to a large segment of the computer user community. We supply approximately 10,000 private, commercial, and industrial EDP installations in the United States with reports on technology and manuals which are updated to reflect this rapidly-moving area of our economy.

Rapid implementation of new technology has bred an environment which is fraught with false claims and poor products. The gains inherent in taking advantage of good opportunities to apply technology, however, should not be overlooked as a result of these problems.

Hi-technology has a use only in its application to a product which serves a useful purpose to the economy. Further, it must have a broad application and be readily understood if it is to be successfully utilized.

Our goal is to publish useful updated material which enables the using industrial and commercial organization to apply the technology in a cost-effective manner. One of our prime sources of information is the Institute of Computer Science and Technology of the National Bureau of Standards. Although their major purpose is support of government agencies, we find that they are willing to share their hard-won practical experience and research knowledge with us and our using corporations. We, of course, respond to the best of our ability with information useful to them. We buy their reports and distribute them to our users at no cost. We visit their facilities and discuss pertinent problems with them. As taxpayers, we feel the Computer Institute is an outstanding investment of our tax dollars and, if anything, the existing budget should be significantly increased.

We think most highly of the direction, Mr. J. Burrows, and feel that the outstanding results of the Institute can be attributed to his executive and technical management.

Thank you for taking the time to read this letter. Attached are some brochures on selected products that include users which are representative of the FTP Technical Library.

Sincerely,

DR. ROBERT S. SNOYER, *President.*